dicates whether there is a possibility of a stack corrosion problem.

In combination with the CO_2 value, net stack temperature is used to determine efficiency; some examples of typical efficiencies are given in the next section, "Combustion Efficiency."

A high stack temperature indicates that heat is being wasted to the atmosphere. Good practice dictates that stack temperature should be kept as low as possible without causing condensation of moisture together with sulfur oxides. If the flue gases should cool below their dew point (the point at which water vapor and sulfur oxides first condense as liquid), corrosion problems could result. The dew point depends on the sulfur content of the flue gas. As a rule, minimum stack temperatures for trouble-free operation are as shown below:

Fuel	Sulfur, %	Minimum Actual Stack Temperature °C	°F
Diesel type	1	140	280
Heavy oil	2.5	155	310
Heavy oil	3.5	160	320

With bare steel stacks and ductwork, the temperature of the metal itself (which is exposed on one side to relatively cool air) can fall below the temperature of the hot gas. Even though the gas may be at a safe temperature, say 400°F (200°C), the inner surface of the metal may be at some lower temperature, say 250°F (120°C), which means that acid dew will form there. Experience has shown that corrosion will not be serious if the metal is kept above 240°F (115°C). This can be accomplished by insulating the exposed metal ductwork. A metal stack can be protected by an aluminum outer shroud (with a ¼-inch air space), or it can be left bare and replaced as necessary. Masonry stacks have an advantage in this respect, but to avoid corrosive action on the mortar, they are best provided with a glazed tile liner.

An overly high stack temperature, say, about 750°F (400°C), may indicate one of the following conditions:

1. Excessive draft.
2. Dirty, carbon-covered heating surfaces.
3. Poor design of heat exchange surfaces, e.g., lack of sufficient baffling in the furnace or boiler, causing short circuits.
4. Undersized furnace.
5. Incorrect or defective combustion chamber.
6. Overfiring of boiler or furnace.
7. Poor draft regulation.

In many cases it will be uneconomical to make changes to bring the stack temperature down, and the best that can be done is to try to operate at minimum excess air to minimize the giveaway of efficiency.

A log of stack temperature with time is useful as a means of predicting when a boiler needs cleaning. A progressive rise in temperature indicates progressive fouling of heat exchange surfaces.

Combustion Efficiency

By use of the carbon dioxide and temperature measurements described above, the efficiency of combustion can be determined. Figures 1 through 4 show typical efficiencies for various stack temperatures and CO_2 readings for four common fuels: fuel oil, liquefied petroleum gas, natural gas, and bituminous coal.

Thermal efficiency as discussed here is the usable percentage of heat extracted by the boiler from the *gross heat content* of the fuel. Losses include sensible heat content of the stack gas, radiation, and the *latent heat of water vapor* produced from hydrogen in the fuel. Another method of calculation is employed in Germany and elsewhere in Europe in which efficiency is the percentage of usable heat extracted from the *net (lower) heat content* of the fuel. Losses include only radiation and sensible heat of the stack gases. An efficient boiler that shows 84% on the gross heat calculation will show about 92% on the net heat calculation. The amount of steam made per unit of fuel fired is, of course, exactly the same. Table 1 illustrates savings available by increasing combustion efficiency.

Smoke Measurement

The amount of smoke in the stack gases can be used to estimate the cleanliness of combustion. Smoke measurement can be used to detect substoichiometric combustion, which usually produces sooty conditions.

Smoky combustion can indicate one or more of the following conditions:

1. Improper fan delivery.
2. Insufficient draft.
3. Poor fuel supply.

TABLE 1

SAVING FOR EVERY $100 FUEL COSTS
BY INCREASING COMBUSTION EFFICIENCY
(Assuming constant radiation and other unaccounted-for losses)

From an original efficiency of:	To an increased combustion efficiency of:								
	55%	60%	65%	70%	75%	80%	85%	90%	95%
50%	$9.10	$16.70	$23.10	$28.60	$33.30	$37.50	$41.20	$44.40	$47.40
55%		8.30	15.40	21.50	26.70	31.20	35.30	38.90	42.10
60%			7.70	14.30	20.00	25.00	29.40	33.30	37.80
65%				7.10	13.30	18.80	23.50	27.80	31.60
70%					6.70	12.50	17.60	22.20	26.30
75%						6.30	11.80	16.70	21.10
80%							5.90	11.10	15.80
85%								5.60	10.50
90%									5.30

FIGURE 1
FUEL OIL COMBUSTION EFFICIENCY*

Appendix A-1

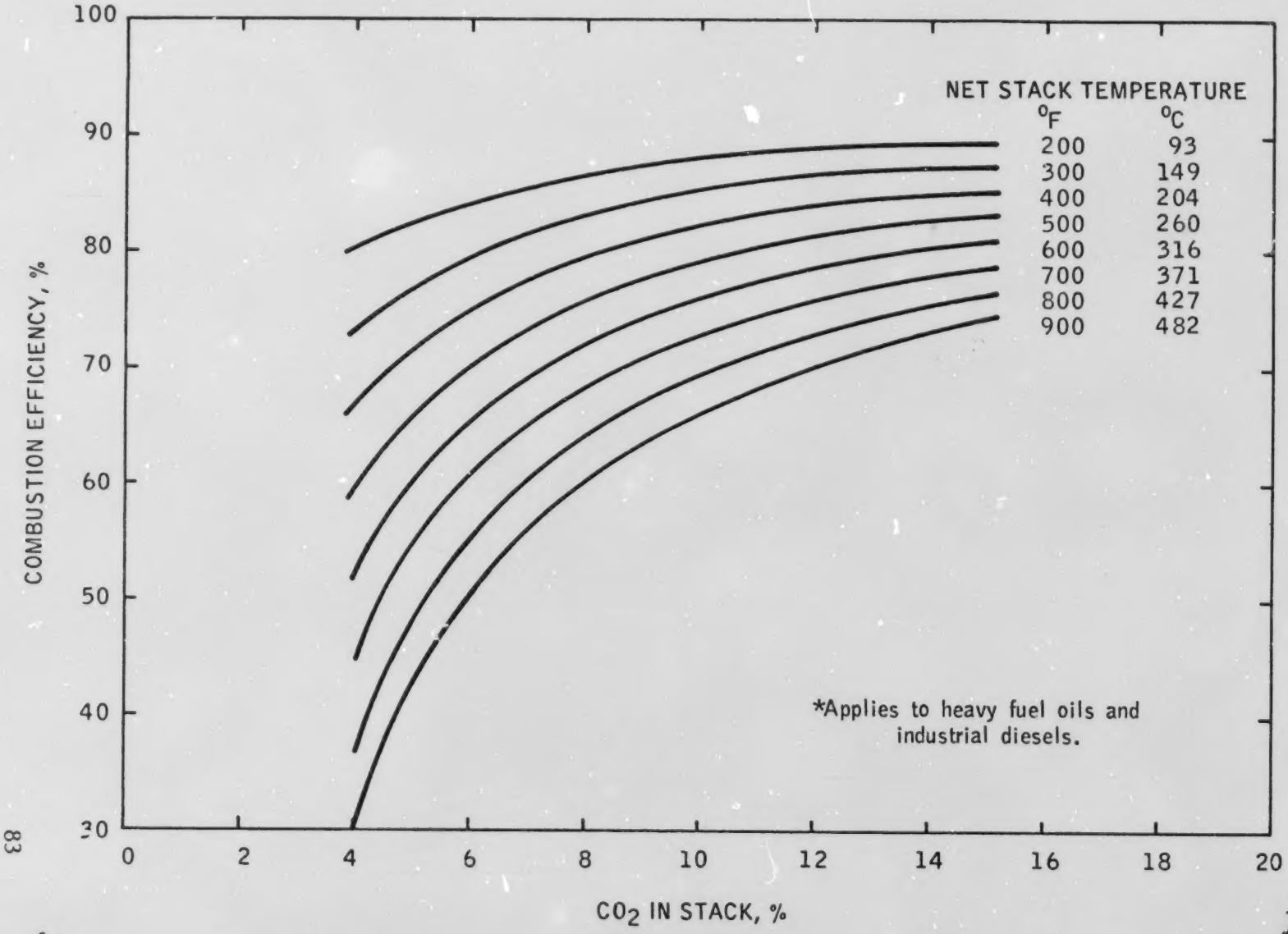

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FIGURE 2
LPG COMBUSTION EFFICIENCY*

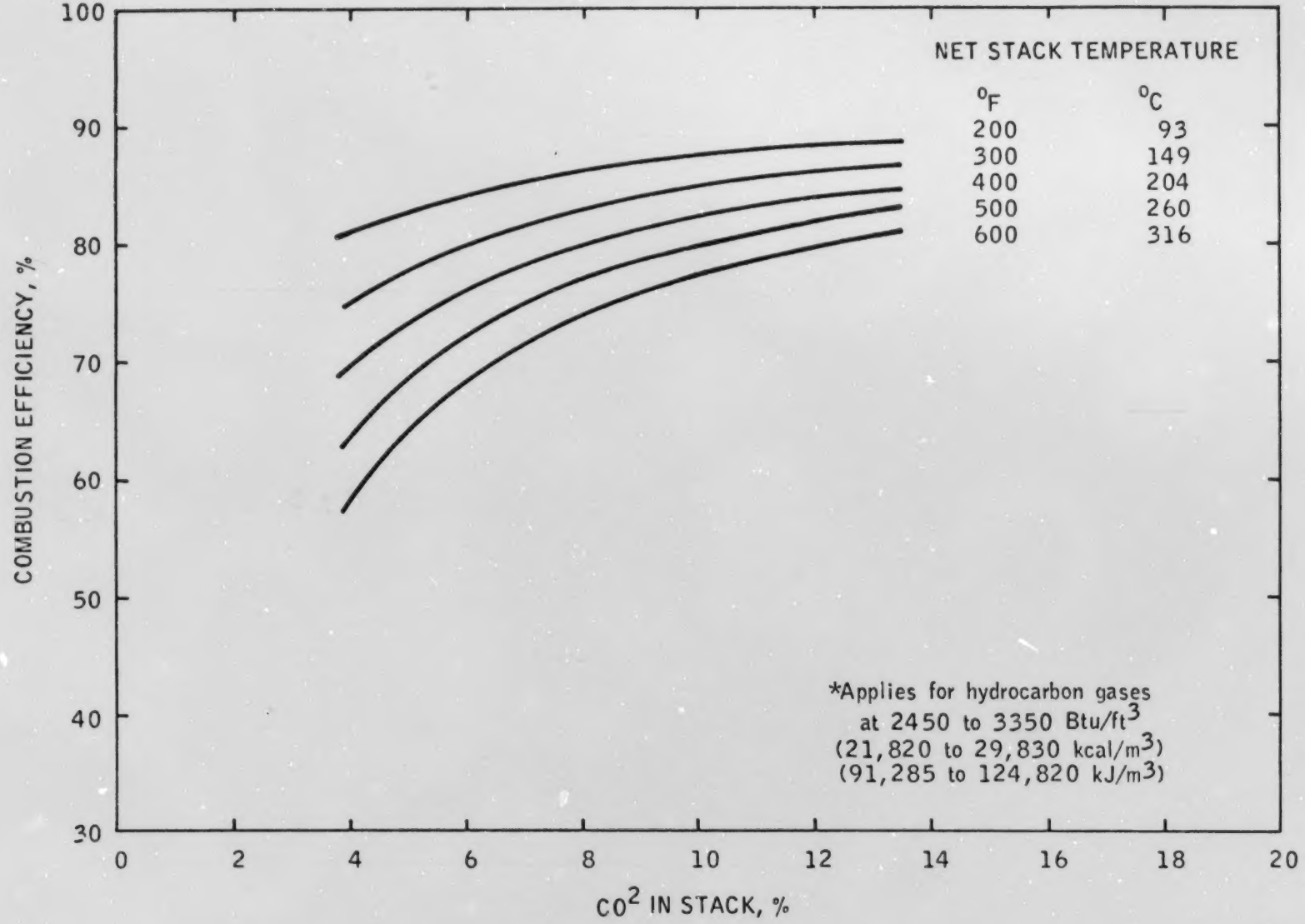


FIGURE 3
NATURAL GAS COMBUSTION EFFICIENCY*

Appendix A-1

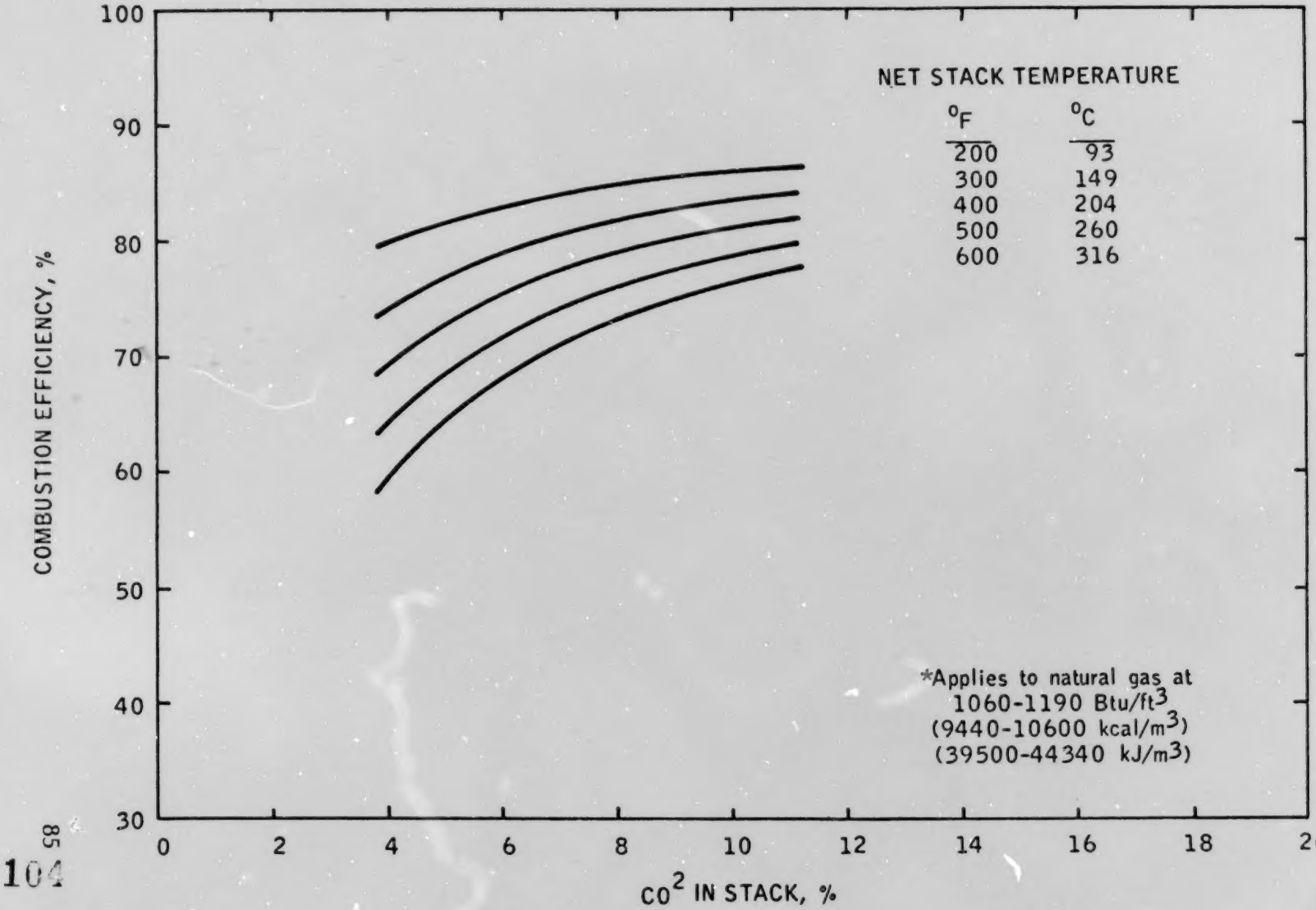
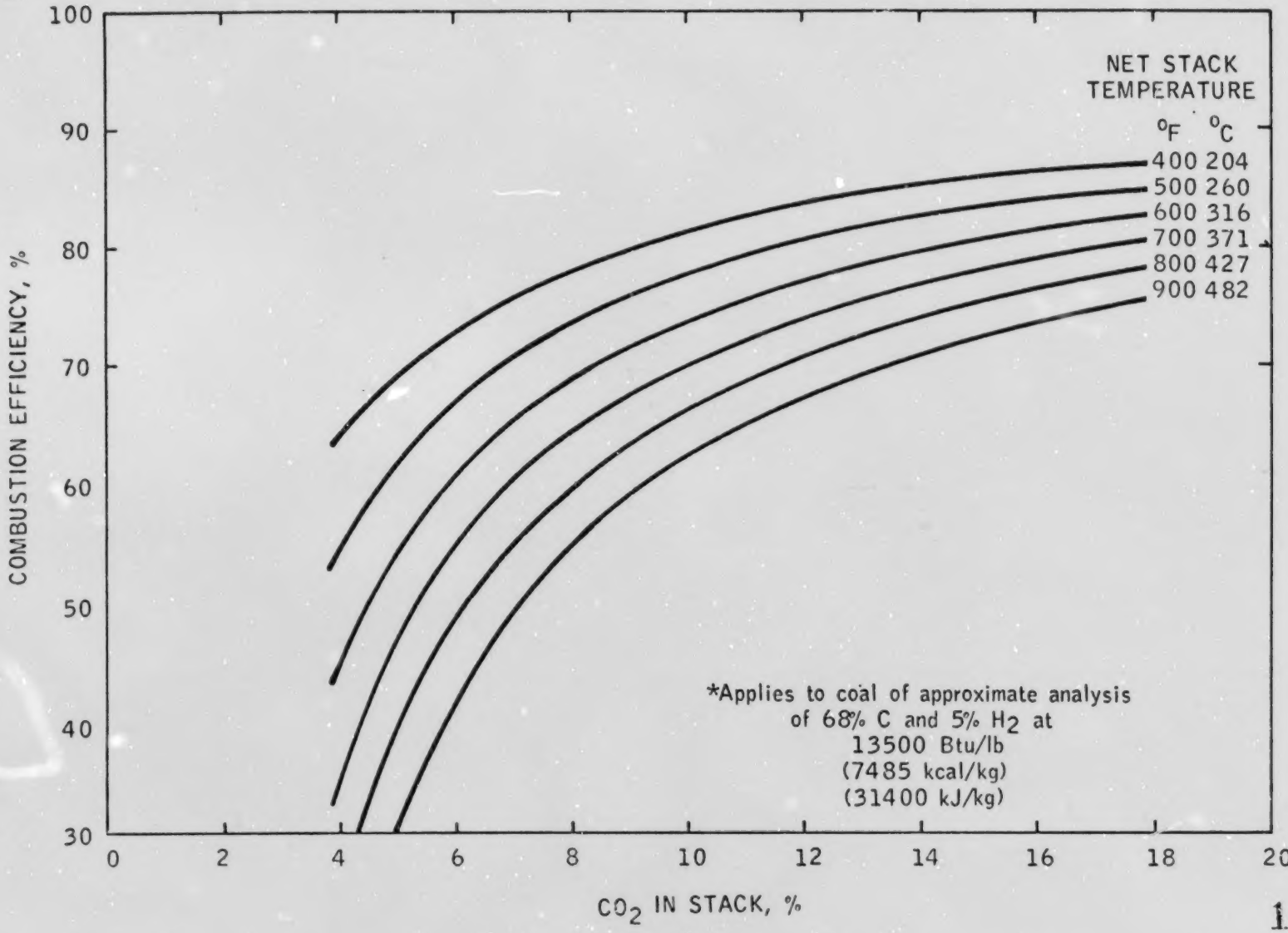


FIGURE 4
BITUMINOUS COAL COMBUSTION EFFICIENCY*

Appendix A-1



4. Malfunctioning oil pump.
5. Defective or incorrect fuel nozzle.
6. Excessive air leaks.
7. Improper fuel-air ratio.

Simple smoke measurements can be made by pulling a fixed volume of flue gas through a filter paper and comparing the color of the paper with a set of standards. The standards vary somewhat according to the equipment manufacturer, so instructions accompanying each instrument should be followed. Because some combustion units accumulate soot more rapidly than others, first-hand experience also plays a part in deciding maximum smoke permitted.

Because smoky combustion indicates inefficient operation and results in carbon build-up on heat transfer surfaces, smoke should be kept to a minimum. When combustion conditions are adjusted, maximum CO_2 should be controlled at a point that does not cause more than Bacharach 4 smoke with heavy oil, or more than Bacharach 2 for diesel fuel, or comparable ratings on the Dwyer instrument.

Draft Measurement

Correct draft is essential for efficient burner operation. While draft is not directly related to combustion efficiency, it does affect burner efficiency. The intensity of the draft, coupled with the setting of the air register, determines the rate at which combustion gases pass through the furnace or boiler.

Excessive draft can increase the stack temperature and reduce the percentage of CO_2 in the flue gases. Too little draft can result in insufficient combustion air and smoky operation. At perfect draft, the flame bushes out to nearly fill the firebox, giving maximum time for clean burn-out.

Draft readings are usually taken in the firebox (overfire draft) and in the stack. Low draft in the firebox can result in leakage of smoke and other combustion products into the surrounding area. Stack draft must be high enough to prevent positive pressure in the combustion chamber; this could happen where a forced-draft fan is used.

Appendix A-2: Energy Survey Form

Btu Conversion Calculations

Annual energy consumption	*Conversion factor*	*Total Btu/year*
Electricity		
____ kWh	× 0.003412	= ____ 10^6 Btu/year
Purchased steam		
____ 10^3 lb.	× 0.97	= ____ 10^6 Btu/year
Natural gas		
____ 10^3 ft^3	× 1.03	= ____ 10^6 Btu/year
Oil (No. 2)		
____ gallons	× 0.14	= ____ 10^6 Btu/year
Oil (No. 6)		
____ gallons	× 0.15	= ____ 10^6 Btu/year
Coal		
____ tons	× ____ (~25)	= ____ 10^6 Btu/year
Other		
____	× ____	= ____ 10^6 Btu/year

Conversion Factors

kWh = 3,413 Btu
Ton of cooling = 12,000 Btu/hr.
Ton-hour of cooling = 12,000 Btu
Horsepower = 0.75 kW
Horsepower-hour = 0.75 kWh

Heat Content

Bunker fuel oil = 150,000 Btu/U.S. gallon
Distillate fuel oil = 140,000 Btu/U.S. gallon
Natural gas = 1,030 Btu/ft^3
Coal (approximate) = 11,000 to 13,000 Btu/lb.

ENERGY SURVEY FORM

INSTITUTION: _____ NO. _____ HEGIS NO. _____ GROSS SQUARE FEET _____ FTE _____

BUILDING: _____ NO. _____ HEGIS NO. _____ GROSS SQUARE FEET _____ FTE _____

MONTH	HEATING DEGREE DAYS	COOLING DEGREE DAYS	PURCHASED ELECTRICITY								PURCHASED STEAM				
			KW·H COST	KW DEMAND CHARGE	POWER FACTOR ADJ.	FUEL ADJ.	TOTAL COST	MAX. KW DEMAND	KW·H USED	10^6 BTU	STEAM COMMODITY COST	STEAM DEMAND CHARGE	TOTAL STEAM COST	STEAM USED 10^3 LBS	10^6 BTU
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
JAN.															
FEB.															
MAR.															
1ST QTR.															
APR.															
MAY															
JUNE															
2ND QTR.															
JULY															
AUG.															
SEPT.															
3RD QTR.															
OCT.															
NOV.															
DEC.															
4TH QTR.															
YEAR TOTAL															

ENERGY SURVEY FORM

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Appendix A-2

MONTH	OIL, HEAVY			OIL, LIGHT			NATURAL GAS					COAL		
	TOTAL COST	GALLONS USED	10^6 BTU	TOTAL COST	GALLONS USED	10^6 BTU	COMMODITY COST	DEMAND CHARGE	TOTAL COST	10^3 FT^3 USED	10^6 BTU	TOTAL COST	TONS USED	10^6 BTU
1	17	18	19	20	21	22	23	24	25	26	27	28	29	30
JAN.														
FEB.														
MAR.														
1ST QTR.														
APR.														
MAY														
JUNE														
2ND QTR.														
JULY														
AUG.														
SEPT.														
3RD QTR.														
OCT.														
NOV.														
DEC.														
4TH QTR.														
YEAR TOTAL														

ENERGY SURVEY FORM

Appendix A-2

MONTH	OTHER					TOTALS						
1	31	32	33	34	35	TOTAL ENERGY COST 36	COST / FT² 37	TOTAL 10^6 BTU USED 38	TOTAL 10^6 BTU / FT² 39	ELECTRIC KW·H / FT² 40	PURCHASED STEAM 10^3 POUNDS / FT² 41	OIL, COAL, GAS 10^6 BTU / FT² 42
JAN.												
FEB.												
MAR.												
1ST QTR.												
APR.												
MAY												
JUNE												
2ND QTR.												
JULY												
AUG.												
SEPT.												
3RD QTR.												
OCT.												
NOV.												
DEC.												
4TH QTR.												
YEAR TOTAL												

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Appendix A-3: Operation of a Boiler Plant

This example of boiler plant operation is an actual case found in a boiler plant providing heat and hot water for a large urban housing project. While not an educational facility, it is similar in size and operation to the facilities found in many educational institutions. The plant had five boilers, three located in the main boiler room, and two located in an annex. They were all natural draft, fire-tube boilers with rotary-cup burners, and operated in an on-off mode. The boilers were inspected for the purpose of determining their operating efficiency and judging if improvements were possible with the limited funds available to the city government.

Visual inspection indicated that all boilers were being operated with their doors open. The operators stated that having the doors open allowed them to observe the fire and detect smoke. The inspectors proceeded to determine the efficiency of one of the boilers as they were found. Efficiency was determined by measuring the temperature and carbon dioxide (CO_2) content of the flue gas leaving the boiler.

It was determined that the boiler had a heat absorption efficiency of 67%. The door of the boiler was then closed and the efficiency was determined again, making no other changes. This time the boiler efficiency was determined to be 77%. Although 77% efficiency is not considered good, it is a significant improvement over 67% (see table 1).

The reason for this improvement is related to the amount of excess air going through the boiler. Excess air is that air going through the boiler over and above the amount theoretically needed to burn the fuel. In order to compensate for the mechanical designs that do not permit perfect operation, boilers such as these should operate without smoke with 25% to 50% excess air.

It is easy to determine excess air from the carbon dioxide measurement, and, in fact,

TABLE 1
Change in Efficiency

Door	Flue Gas	CO_2	Excess Air	Efficiency
Open	600°F	6.0%	153%	67%
Closed	570°F	9.0%	71%	77%

graphs and tables are available that establish the relationship between carbon dioxide and excess air for various fuels. In this case, the boiler with the door open showed 153% excess air, which dropped to 71% when the door was closed. The extra gas going through the boiler in the form of excess air must be heated, and that heat is carried out of the boiler with the flue gas, and therefore is not available to make steam.

Excess air in the five boilers tested, measured with the doors closed, ranged from 71% to as high as 202%. It soon became obvious that a great deal of extra air was being used in order to keep the boilers from smoking (see table 2).

TABLE 2
Boiler Efficiencies

Boiler	Flue Gas	CO_2	Excess Air	Efficiency
1	425°F	5.0%	202%	73%
2	480°F	5.5%	175%	72%
3	470°F	5.0%	202%	71%
4	520°F	7.5%	104%	76%
5	570°F	9.0%	71%	77%

At the outset, it was stated that these boilers were fitted with rotary cup burners; these burners have a cone-shaped cup rotating at high speed (see figure 1). The fuel is atomized

by the centrifugal force as the oil is thrown off the large end of the cone. In order to work properly, the rotary cup must be clean and smooth, with a sharp edge.

It was found that the burners in this boiler plant were not properly maintained. The cups were distorted and had chipped edges, which caused the production of large drops of oil that struck the furnace wall and caused smoke. The high excess air levels were used to minimize the smoke. By replacing the rotary cups on these burners, the excess air levels were reduced below 50%, which increased the efficiency to about 80%.

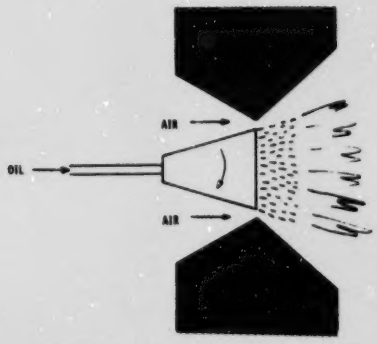

Figure 1. Rotary Cup Burner

It was stated that these boilers operated in the on-off mode. That is to say, when more steam is required, the burners come on, and when the demand is satisfied, the burners shut off. The steam demand is easily determined by sensing the steam pressure, which will drop as steam is consumed. When the burners are off, the natural draft continues to pull room air through the boiler, which carries away heat. These losses are referred to as downtime draft losses, and are estimated to vary from 4% to 15% in these boilers. This loss can be eliminated by installing draft regulators on the boilers, which will prevent air from moving through the boilers when the burners are not firing.

Another suggestion to improve operation is to install programmers to insure that only those boilers needed to meet the load are fired. The existing practice was that all boilers would come on together when steam was called for.

A final improvement that was suggested was to install devices in the fire tubes of the final pass, which increase heat transfer, thereby lowering stack temperature; these devices are called turbulators. The lower stack temperature that results is a direct indication of increased boiler efficiency. The upper tube row shown in figure 2 is where the turbulators would be installed.

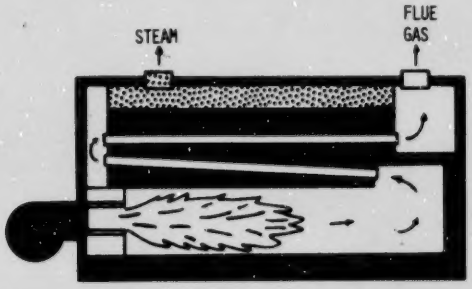

Figure 2. Fire Tube Boiler

The net result of improvements in this boiler plant was estimated to result in a boiler efficiency of 85%, saving $40,000 each year for a total investment of under $20,000. This example may seem extreme, but is not too uncommon for this class of installation, which has been accustomed to cheap fuel.

Appendix A-4: Graphing the Data (Weather Effects)

The energy survey form developed by the Association of Physical Plant Administrators under the auspices of the Energy Task Force has been recommended for use in accumulating monthly data on fuel consumption and energy costs. Some of the data are amenable to graphing, and the graphs can be useful in several ways, such as:

1. They permit separation of the base load from the weather-dependent load, and lead to such questions as: Where is the base load going?
2. They permit comparison of energy consumption with that of other institutions.
3. They can be posted on bulletin boards to explain improvements to students and faculty, to generate interest in the energy problem, and perhaps to attract volunteers to make further analyses.

To separate the base load from the weather-dependent load, the total fuel and steam energy (not electricity) are compared in a graph with the monthly accumulation of degree days. For example, over the seven months of the winter the following data were collected:

	Degree days	10^9 Btu's/month
October	54	7.0
November	229	9.1
December	550	12.4
January	630	13.7
February	580	12.7
March	270	9.2
April	180	8.8

After graphing these data, as in figure 1, the following are determined:

1. A base load, which is independent of weather, of about 6.5 billion Btu's of purchased fuel per month.
2. An increment of 10.6 million Btu's/degree day.

If improvements are made, this graph will alter both in *base load* and in *slope* for the following winter. Even if the following winter should prove to be exceptionally cold or exceptionally mild, the slope, which is based on degree days, will compensate for that, and perhaps a reduction of consumption to 8.5 million Btu's/degree day will be realized.

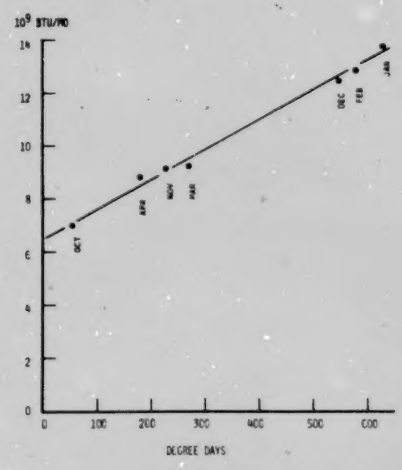

Figure 1. Winter Energy Consumption

The actual slope and shape of the line shown in the graph may be influenced by wind, humidity, and the number of consecutive days that the cold weather persists.

Another useful graph is one that shows the proportions of current use charge, demand charge, and power factor charge in dollars per month (see figure 2). The purpose of this graph

is to view the relative distribution of the electricity billing to see whether there are particular months that cause either a low or high demand factor, or a low or high power factor. When such aberrations are observed, the question is raised, "What load has been taken off, or put on, in that particular month to cause the change in the structure of the bill?" That might well indicate what could be done to avoid a high demand, or to schedule operations to come down to the "best-month" conditions, for the whole year.

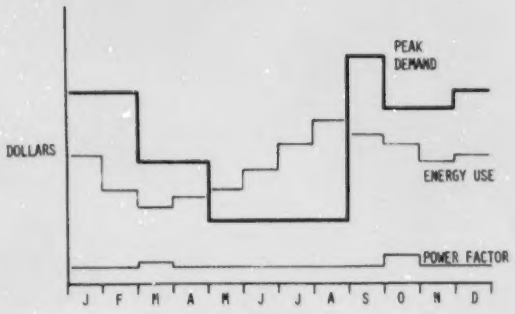

Figure 2. Annual Electricity Costs

Appendix B: Energy-Saving Measures

Lighting

Quick Fix

Turn Off Lights

- Mark all ganged switches with identification indicating the lights controlled. Color-code switches and institute a program of effective lighting usage.
- Instruct occupants and maintenance personnel to switch off all lights that are not required.
- Turn off all lights other than those needed for security and egress when the building is unoccupied.
- Substitute small table- or floor-mounted lamps in lounge areas or waiting rooms and turn off modular ceiling fixtures.
- For cleaning that must be done at night, turn on lights only in that portion of the building being cleaned.
- Turn off flood lighting that is strictly decorative.

Utilize Daylight as Practicable

- Clean windows and skylights.
- Where practical, schedule cleaning and meetings during periods of building occupancy to make maximum use of daylight.
- Locate tasks that need the best illumination closest to the windows, with the task-viewing angle parallel to the windows.
- Switch off electric lights in areas when natural light is available.
- Increase the inter-reflectances of interior surfaces.
- To reduce glare, rearrange work stations so that side wall daylight crosses perpendicular to lines of vision.

Improve Maintenance

- Light output should be checked regularly with a calibrated light meter by maintenance personnel. When the light output of a group of lamps has fallen to approximately 70% of the original light output, relamp all fixtures in the group at the same time. This is also a good time to check whether a more efficient or lower wattage lamp is suitable.
- Lamps should be wiped clean at regular intervals to assure maximum efficiency. Lamps exposed to an atmosphere with substantial dirt, dust, grease, or other contaminants should be cleaned more frequently than lamps in a relatively clean atmosphere.
- The efficiency of fluorescent lighting fixtures can be maintained by cleaning reflecting surfaces and by replacing shields that have yellowed or become hazy with a clear acrylic lens with nonyellowing properties. For some applications, a clear glass lens can be considered if it is compatible with the fixture and does not present a safety hazard. (Caution should be used to insure that an existing fixture will safely support and hold the glass lens.)
- Clean ceilings, walls, and floors frequently to improve reflective qualities. When daylight is used, wash windows frequently to maintain illumination levels on tasks requiring some natural illumination.

Modify Illumination Levels

- Illuminate specific task areas to that level, for each area, which provides adequate lighting to perform the required task satisfactorily and reduce illumination levels in adjacent areas. Follow recommendations in chapter 4.

Remove or Replace Lamps

- Remove unnecessary lamps if removal will still enable provision of illumination levels re-

quired. When lamps are removed from a fluorescent fixture, all lamps controlled by a given ballast should be removed to prevent ballast failure or reduced lamp life. Except in the case of instant-start lamps or fixtures with circuit-interrupting lamp-holders, also consider disconnecting ballasts, which otherwise would continue to consume energy.

- Consider replacing present lamps with those of lower wattage, which still provide adequate illumination. Be certain that new lamps are compatible for use with existing ballasts in fluorescent and high-intensity discharge (HID) fixtures.
- Use a single, larger incandescent lamp where possible, rather than two or more smaller lamps. Higher wattage, general-service incandescent lamps are more efficient than lower wattage lamps.
- Avoid multilevel lamps. The efficiency of a single-wattage lamp is higher per watt than a multilevel lamp.
- Avoid using extended service lamps except in special cases, such as recessed directional lights, where short lamp life is a problem.
- When relamping, replace 40-watt fluorescent lamps with 35-watt lamps to achieve a reduction in lighting level of approximately 18%, while saving 20% in fixture electrical energy.

Refit

- Replace louvers and lenses and install lenses to give better quality and more efficient lighting on tasks. Lenses should be selected for low brightness and high efficiency.
- Remove all louvers and lenses in areas where coefficient of utilization will be improved and the additional glare can be tolerated. Where lenses are necessary to control glare, use efficient type.
- Provide manual switches or photocells to shut off lights when available daylight is adequate to replace the required lighting.
- Install additional switches to permit shutting off lights in unoccupied areas.
- In areas where occupancy is light or erratic, install time switches that automatically turn off lights at a preset time and that require manual switching to energize the lights again after that time.
- Install photocells or electric timers to shut off outdoor parking lot lights at night, during weekends, and at other times when lots are not in use. Schedule operation of photocells and electric timers to the working shifts of employees.
- Install neon pilot lights to alert personnel that lights are on in adjacent areas that are totally enclosed.
- Replace incandescent fixtures with more efficient fluorescent or other more efficient fixtures, depending on application.
- When replacing fixtures, select that type with higher coefficient of utilization.
- Replace all incandescent parking lot lights with mercury vapor, high-intensity discharge (HID) lamps.
- Remove display lighting fixtures in retail stores, bulletin boards, and other areas where inefficient incandescent lamps are used. Substitute fluorescent fixtures only where required.
- Paint or apply light reflective colors on interior room surfaces to increase interreflectances and to improve the performance of both natural and artificial illumination. Walls should be first in priority, then ceiling and floors.
- Where partitions cannot be removed entirely, install low partitions, perhaps with transparent material to the ceiling, to reduce light absorption while permitting the use of "borrowed" light from adjacent spaces.
- When refurnishing, select lighter-colored furnishings that do not have a glossy surface.

Systems Convert

- Use air-extract fixtures to redistribute captured heat from interior zones to perimeter zones to supplement heating requirements.
- Consider installing a master switching system, using low-voltage switching to permit an operator at one or more stations to turn off all lights at the end of occupied periods. Seven-day timers can also be used to automatically program lights.
- Modify existing fixtures to accommodate higher efficiency lamps. For instance, convert incandescent lamp fixtures to HID lamps or convert existing HID lamps to newer or more efficient ones.
- When undertaking alterations, use open landscape planning to the greatest extent pos-

sible. This will reduce the amount of light energy that would be absorbed by walls.

•When retrofitting a building, lower the fixture mounting height.

•Install multilevel ballasts and integral switches to reduce lighting levels.

Heating and Cooling

(Modification of General Operating Practices)

Quick Fix

•Shut down cooling equipment at night and during days when the building is unoccupied.

•Install warm-up cycle controls on air handling units with outside air intake to permit outside air dampers to remain closed during building warm-up or cool-down.

•Reduce use of heating and cooling systems in spaces which are used infrequently or for short periods of time.

•Cool office, general purpose, academic, and residential buildings to 80°F. Special consideration should be given to computer rooms and research areas.

•Begin precooling operations before occupants arrive. Complete cool-down during the first hour of occupancy.

•Heat general-purpose and academic buildings to 65°F when occupied. (See chapter 4 for recommendations for other areas.) This does not mean that air should be cooled if the temperature exceeds 65°F.

•Consider the following guidelines for heating temperature setback during unoccupied periods:

•Shut off radiators or registers in lobbies.

•Adjust automatic timers or add time clocks for night and weekend operation for all areas occupied infrequently.

•When buildings are used after hours for meetings, conferences, cleaning, or scattered activities, reduce the number of spaces occupied and, to the extent possible, consolidate activities in the same section of the building. Also reduce temperature and turn off humidifiers.

•When there is no danger of freezing, turn off radiators or supply registers in areas that do not have a separate thermostat. Open them when building is occupied.

•Check relevant codes requiring protection for plumbing, fire sprinkler systems, and standpipes before implementing extreme temperature reduction. Public utilities may set temperature requirements for their equipment rooms.

•Advise occupants to wear heavier clothing when indoor temperatures are lowered.

•In large heated areas such as storage spaces that are occupied by only one of two people, reduce temperatures to a level just sufficient to prevent damage to other systems (plumbing, sprinkler systems, etc.). Consider local radiant heaters instead of central heating systems.

•Evaluate the necessity of humidification systems and curtail humidification in lobbies, corridors, laundries, cafeterias, kitchens, etc., where equipment or process requirements do not take precedence.

•Allow natural humidity variation from 60% to 70% r.h. in occupied spaces.

•Turn off all humidifiers at night and during unoccupied periods.

•Turn off portable electric heaters and portable fans when not needed and during unoccupied periods.

•Turn on self-contained units, such as window and through-the-wall units, only when needed. Turn them off when the space is to be unoccupied for several hours.

•Turn off reheat in all areas during summer, except where equipment requirements necessitate humidity control.

•When the sun is not shining during the heating season, close interior shading devices to reduce radiation to cold window surfaces.

•Develop an after-hours equipment operation checklist for use by custodial and other building personnel as well as occupants who may use various spaces after normal periods of occupancy.

•Schedule operating and maintenance work during the daytime, if possible.

•Reduce internal heat generation as much as possible during the cooling season. Typical sources of heat generation include lighting, people, machines, and cooking equipment.

Refit

•Adjust and balance heating and cooling systems to minimize cooling and overheating

which results from poor zoning, poor distribution, improper location of controls, or improper controls.

(Modification of HVAC System Operating Practices)

Quick Fix

Terminal Reheat System

- De-energize or shut off reheat coils and raise chilled water supply air temperature in summer months in increments of 3°F to determine the highest supply temperature that will maintain satisfactory room conditions.
- Reduce supply air quantity.
- Adjust outside air, return air, and mixed-air damper controls in winter to raise supply air temperature to the proper level, depending on conditions in the area served by the system.
- If close temperature and humidity control must be maintained for equipment purposes, lower water temperature and reduce flow to reheat coils. This will still permit control, but will limit the system's energy requirements.

Dual Duct System

- Refer to "Terminal Reheat System" for general recommendations applicable to dual duct system.
- Lower hot deck temperature and raise cold deck temperature.
- Reduce air flow to all boxes to minimally acceptable level.

Multizone System

- Set controls to reduce hot deck temperatures and increase cold deck temperatures, consistent with the loads of critical zones. While this will lower energy consumption, it also will reduce the system's heating and cooling capabilities as compared to current levels.

Induction System

- Refer to "Terminal Reheat System" for general measures also applicable to induction systems.
- Inspect nozzles. If metal nozzles, which are common on most older models, are installed, determine if the orifices have become enlarged from years of cleaning. If so, chances are that the volume/pressure relationship of the system has been altered. As a result, the present volume of primary air and appropriate nozzle pressure required must be determined. Once done, rebalance the primary air system to the new nozzle pressures and adjust individual induction units to maintain airflow temperature. Also inspect nozzles for cleanliness. Clogged nozzles provide higher resistance to air flow, thus wasting energy.
- Set induction heating and cooling schedules to minimally acceptable levels.
- Reschedule the temperature of heating water and cooling water according to load. Avoid simultaneous heating and cooling in any one zone.
- Schedule the temperature of the primary air supply in air handling units according to load. Achieve modulation, preferably by adjusting water temperature. This modification may result in increased maintenance due to wet coils.
- For operation during unoccupied hours in the heating season, shut down primary air fans, raise the hot water temperature, and operate induction units as gravity convectors.

Single Zone System

- Implementing energy conservation measures that reduce the heating and/or cooling of air handled by the HVAC system will result in reduced fan power input requirments. Fan brake horsepower varies directly with the cube of air volume. Thus, for example, a 10% reduction in air volume will permit a reduction in fan power input of about 27%. This modification will limit the degree to which the zone serviced can be heated or cooled as compared to current capabilities.
- Raise supply air temperatures during the cooling season and reduce them during the heating season in accordance with thermal needs. Adjust chilled water and hot water temperatures to provide adjusted supply air temperatures.
- Avoid simultaneous heating and cooling except as required for humidity control in critical areas.

Fan Coil System

- Refer to "Single Zone System" for general recommendation applicable to fan coil system.
- When heating and cooling loads are mini-

mal, shut off fans to enable the coil to act as a convector.

- Consider installing interlocks between the heating and cooling coils of each unit to prevent simultaneous heating and cooling.
- Block off outdoor air inlets where no dampers are installed if infiltration meets ventilation requirements.

Constant Volume System

- Determine the minimum amount of airflow that is satisfactory and reset the constant volume device accordingly.
- Investigate the possibility of converting the system to variable (step-controlled) constant volume operation by adding the necessary controls.

Variable Air Volume System

- Reduce the volume of air handled by the system to a point that is satisfactory.
- Lower hot water temperature and raise chilled water temperature in accordance with space requirements.
- Lower air supply temperature to meet the maximum load.
- Operate variable volume reheat systems similar to procedures described for terminal reheat.

Self-Contained Systems

- Turn off cooling units and fan when leaving space.
- Install timers to shut units off automatically.

Refit

Terminal Reheat System

- If humidity control is not required, convert the system to variable volume by adding variable volume boxes and eliminating terminal heaters.
- Install controls to minimize simultaneous heating and cooling if converted to reheat-variable volume.

Dual Duct System

- Replace obsolete mixing boxes or repair defective ones to minimize leakage of hot or cold air when the respective damper is closed.
- Provide volume control for the supply air fan and reduce capacity, preferably by speed reduction, when both hot deck and cold deck air quantities can be reduced to meet peak loads. Reducing heat loss and heat gain provides an opportunity to reduce the amount of air circulated.
- When there is more than one air handling unit in a dual duct air system, modify ductwork so that each unit supplies a separate zone. This provides an opportunity to reduce hot and cold duct temperatures according to shifting loads.
- Change dual duct systems to variable volume when energy analysis is favorable and the payback in energy saved is sufficiently attractive. Do this by adding variable volume boxes and fan control.

Multizone System

- Consider converting system entirely or in part to variable volume by adding terminal units and pressure by-pass and/or add fan coil units in specific areas requiring constant air volume.
- Consider installing automatic control valves that will regulate hot and cold deck temperatures according to demand. When properly installed, and with all hot deck or cold deck dampers partially closed, the control will reduce hot deck temperature and raise cold deck temperature progressively until one or more zone dampers is fully open.

Single Zone System

- Consider converting single zone, single duct systems to variable volume by adding variable volume boxes at each branch. Fan volume should preferably be controlled according to demand either by installing inlet guide vanes or by installing a variable-speed motor.

Fan Coil System

- If fan coils are not located in conditioned areas, insulate the casings to reduce heat loss or gain.
- With three-pipe systems, set control for minimum mixing of hot and cold water. Change to two-pipe operation.

Variable Air Volume System

- Where possible, eliminate reheat coils and set the box to full closeoff.
- If not installed, provide either inlet vortex dampers or variable speed drives such as a multispeed motor. Fan volume will be reduced

when dampers begin to close until one or more variable air volume dampers is fully opened.

Self-Contained Systems

- If multiple units are involved, consider installation of centralized automatic shut-off and manual override controls.
- If units are relatively old, consider replacing them with more efficient air-to-air heat pumps or similar units with higher equivalent efficiency rating.

Ventilation

Quick Fix

- De-energize outdoor air supply fans during unoccupied periods. Use an automatic timer if one is available, or switch off manually. If an automatic damper is supposed to close when the fan shuts down, check to make sure it closes tightly. Repair it with felt edges or other suitable material if it by-passes air.
- Provide general ventilation in accordance with occupancy, not on a continuous basis. In many buildings heavy occupancy occurs at regular intervals, so ventilation can be shut off for certain periods during the day.
- If windows are used to provide ventilation, be sure they are closed at night.
- If air handling units that supply heated or cooled air are equipped with outdoor air inlet ducts and dampers, close dampers during unoccupied periods. If no damper exists, install a felt-lined one with a remote or local control device and timer control.
- When outdoor air dampers are not operating on economizer cycle, close them for the first and last hours of occupancy if outdoor air has to be heated or cooled.
- Shut off exhaust fan hoods in laboratories, kitchens, bakeries, and cafeterias when operations are completed. Add control damper or gravity damper to keep the air path in the exhaust duct closed when fan is not operating.
- Outdoor air quantities for window units, through-the-wall units, and fan coil units generally are fixed. When these units are used to maintain nighttime or unoccupied cycle room temperatures, the outdoor air intakes are generally open. If dampers are available, close them when outdoor air is not needed. Where infiltration is sufficient for daytime ventilation requirements, block off the outdoor air damper completely for some or all of the units.
- Reduce ventilation rates during occupied periods to a minimum possible, usually about 5 cfm per person.
- Check codes, where applicable, for specification of minimum exhaust level and for rules on recirculation or filtering of air.
- Use an anemometer or other flow meter at the outdoor inlet or louver to measure the amount of outdoor air introduced into the ventilation system. The outdoor air damper setting often differs from the damper indicator setting. Also, realize that a damper blade does not proportion air directly with its opening. A blade with 10% opening permits much more than 10% flow.
- Cut off direct outdoor air supply to toilet rooms and other "contaminated" or potentially odorous areas. Permit air from "clean" areas to migrate to the "dirty" areas through door grilles or undercutting of doors. This is effective if toilet areas have a mechanical exhaust system, or even if ventilated by open windows (especially those on the lee side of the building).
- If outdoor temperature is below 45°F, do not operate the ventilation system any longer than needed. Noticeable odors are good indicators of the need to operate the fan or open outdoor dampers. Flushing out the building until odors disappear will usually be satisfactory.
- Use window ventilation where possible during mild weather. This reduces the power required for mechanical exhaust systems and also the air intake that normally balances the exhaust. Shut off supply air system when window ventilation alone is adequate.
- Concentrate smoking areas together so that one ventilation system can serve them all. Adjust outdoor air to serve those areas and reduce all other outdoor air to systems.
- In buildings with high ceilings, such as auditoriums, which are used for short periods or intermittent operation, outdoor air is frequently unnecessary. For longer periods of light occupancy, outdoor air may still be unnecessary.

• Operate kitchen exhaust systems intermittently throughout the day. Turn them off when they are not needed. Operate them at noon, during coffee breaks, and at heavy cooking times.

• Shut off laboratory hoods in air conditioned areas when not needed.

• Many hoods exhaust much more air than necessary. Reduce the quantity of exhaust air from hoods in laboratories, kitchens, and similar operations by closing off a portion of the hood, changing hood type from canopy to high velocity, or slowing down exhaust fans to the point just necessary to satisfy exhaust requirements.

• Establish a ventilation operation schedule so exhaust systems operate only when they are needed most.

• Do not reduce ventilation rate when outdoor air can be used for economizer or enthalpy cooling.

• Minimize the amount of fresh air intake during heating season in units equipped with mixed air controllers.

Refit

• Rebalance air supply system to provide a maximum of 1 cfm per square foot of supply air to toilet rooms and adjust the exhaust system accordingly. Refer to ASHRAE Standard 62–73.

• Replace outdoor air dampers that leak excessively and thus do not allow accurate control. Use good quality, opposed-blade dampers with seals at blade edges and ends. Be certain damper motors are properly adjusted to close dampers tightly.

• Install charcoal filters or other air treatment devices in exhaust air systems and circulate treated air back into the space to reduce the amount of outdoor air required for make-up for all systems handling 2,000 cfm or more. Supply slightly more outdoor air than exhaust air to pressurize the conditioned space. Approval of code-administering agencies having jurisdiction in the location of the building must be obtained when reducing outside air quantities below code requirements.

• Modify duct systems and hoods and introduce untreated outdoor or return air directly to the exhaust hood. Weigh this against changing hoods to new high-velocity hoods that require less make-up air.

• Consider installing economizer cycle and/or enthalpy controls to air handling units in offices. This will minimize cooling energy requirements by using proper amounts of outdoor and return air to permit "free cooling" with outside air when possible.

• Supply ventilation air to parking garages according to levels indicated by a CO_2 monitoring system.

Infiltration

Quick Fix

• Inspect building exterior and interior surfaces and caulk all cracks that allow outdoor air to penetrate.

• Caulk around all pipes, louvers, and other openings that penetrate the building skin.

• Repair broken or cracked window panes.

• Weatherstrip and caulk exterior doors and windows.

• Be certain that all operable windows have sealing gaskets and cam latches that are in proper working order.

• Cover window air conditioners with plastic covers in the winter unless air conditioners are used for heating.

• Install automatic closers on exterior doors. Consider posting a small sign next to each operable window and door leading to exterior or unconditioned space advising occupants to keep them closed while the building is being heated or cooled.

Refit

• Consider using an expandable enclosure for delivery ports. It reduces infiltration when in use because it can be adjusted to meet the back of a truck, substantially reducing the amount of air that otherwise would infiltrate.

• Consider installation of an air curtain, especially in delivery areas. The device prevents penetration of unconditioned air by forcing a layer of air of predetermined thickness and velocity over the entire entrance opening. (An expert should be consulted before obtaining such a device, especially when high-rise structures are involved. The degree of stack effect,

among other considerations, determines its usability.)

- Consider utilizing revolving doors for the front entrance. Studies have shown that such devices allow far less air to infiltrate with each entrance or exit. Use of revolving doors in both elements of a vestibule is even more effective. If high-peak traffic is involved, swinging doors can be used to supplement revolving doors.
- Consider installation of a vestibule for the front entrance of a building. It should be fitted with self-closing, weather-stripped doors. Sufficient distance between doors must be provided.
- In locations where strong winds occur for long periods, consider installing wind screens to protect external doors from direct blast of prevailing winds. Screens can be opaque, constructed cheaply from concrete block, or can be transparent, constructed of metal framing with armored glass. Careful positioning is necessary for infiltration control.
- Seal vertical shafts and stairs from the rest of the building to reduce infiltration. Check with local fire codes to insure compliance.
- Pressurize buildings with outdoor air, properly controlled and treated, to reduce uncontrolled infiltration.
- Install tight-fitting storm windows where practical.

Heat Transmission

Refit

Wall Insulation

- If remodeling or modernization is contemplated, consider adding insulation to all exterior walls as well as those separating conditioned and nonconditioned spaces. Refer to ASHRAE Standard 90-75 for wall insulation guidelines.
- Give priority to walls in spaces that are continuously occupied for the greatest length of time.
- Check all codes before installing insulation on the interior surface of a building. Some insulation materials are not acceptable due to low ignition temperatures and/or toxic or poisonous fumes when burned.
- Blowing insulation into a masonry wall cavity or stud space should be accomplished under slight pressure. The cavity should be completely filled, since fill insulation often settles with time.
- Provide vapor seal on the room side of insulation.

Floor Insulation

- Insulate slab-on-grade floors that are subject to condensation or that have low surface temperatures.
- Insulate slab-on-grade floors with edge insulation and protect insulation with a waterproof seal.
- Where suspended floors are over a closed-in, but unused, space, apply insulation to the underside of the floor. If, however, there may be some future use for the space, or if it contains pipes and ducts, then apply insulation to the inside walls of the space, leaving the floor uninsulated.

Roof Insulation

- Consider adding roof deck insulation, especially if a building is older than 20 years. Refer to ASHRAE Standard 90-75 for roof insulation guidelines.
- If priorities to insulate roofs are necessary, then insulate a 15-foot-wide band around the perimeter, rather than the entire roof. The roof over the perimeter zones experiences the greatest heating load.
- If the ceiling void is used as a return air plenum, insulation applied to the underside of the roof should be bonded or sealed to prevent migration of fibers, and should not extend over the lighting fixtures.
- If possible, include an air space between insulation boards and the underside of the roof to gain added insulating effect.
- When adding insulation, provide vapor barriers of sufficient impermeability to prevent condensation on the interior surface of the roof.

Modify Fenestration (Windows, Doors, and Skylights)

- Where windows are subjected to high winds in winter and to sunlight in summer, consider prefabricated sunscreen on the exterior of the window. Sunscreens serve a dual purpose: they minimize the effect of heat loss

due to wind and reduce solar heat gains in the summer.

- Install thermal barriers whenever unoccupied hours exceed 70 per week and heating degree days exceed 4500.
- Install storm doors in all locations where degree days exceed 3000 and provide not more than 50% glass area in the storm door. Storm doors should be wood rather than metal, unless a thermal break is provided.
- Where exterior doors are not used during the heating season and are not required as fire exits, caulk the doors, seal them with removable strips, or insulate the areas between the storm door and the existing door, although double windows or storm doors are not cost-effective to reduce cooling loads alone, and are not recommended for that purpose alone. When installed to reduce heat loss, they will also reduce heat gain to a smaller extent in the summer.
- Install temporary plastic shade cover over windows to reduce conduction loss and reduce infiltration rates.
- Where operable storm sash is desired, provide hopper-type windows with 25% of the total sash operable, or sliding windows, casement windows, or double-hung windows to most nearly match existing windows, if matching is an architectural consideration.
- In new additions, minimize the amount of glass on the north side. Where energy required for heating exceeds that for cooling, use minimal glass.
- In new additions, where energy for cooling exceeds the amount of energy required for heating on a seasonal basis, minimize the amount of glass in the west first, then east, south, and north exposures in that order.
- In new additions, where outdoor air conditions are close to desired indoor conditions for a major portion of the year, do not caulk or install double glazing; provide the greatest amount of operable windows to permit natural ventilation and cooling.

Reduce Solar Heat Gain Through Windows and Glass Doors

- Consider installation of horizontal fixed or movable eyebrows over south-facing glass. Install fin sunscreens on the exterior of east, west, and south windows to reduce solar heat gain and wind loads in the winter. In locations where winds are minimal in the winter and/or existing construction and aesthetics preclude locating sunscreens on the exterior, install them on the interior surface of the window. Screens can be hinged to permit easy access to operable windows. Sunscreens tend to reduce available daylight for illumination.
- Install awnings over windows to block out summer sun. Awnings are particularly suitable to shade large display windows.
- Consider installation of storm windows.
- Consider replacing single, clear glass on east, west, and south sides with reflective glass when replacing broken windows, if the windows are in direct sunlight 200 hours or more during the cooling season. Replace all single glass on west, east, and south facades if windows are in direct sunlight 500 or more hours per year during the cooling season. Reflective glass is more effective in reducing heat than heat-absorbing glass.
- Use opaque or translucent insulating materials to block off and thermally seal all unused windows.
- Apply reflective coatings to the inside surface of east, west, and south windows exposed to direct sunlight.
- If double windows are added to reduce heat loss in winter, provide the inner layers with reflective glass to reduce transmission at peak conditions to 50% of maximum.
- Install milium-lined drapes, venetian blinds, or shutters on the inside of all south, east, and west windows subject to direct sunlight in the cooling season and/or exposed to a large expanse of sky. These devices are not as effective as external shading devices or sunscreens, but are less expensive to install.
- Refit skylights in the same manner as windows.

Central Plant Operations

Quick Fix

Boiler Plant

- Isolate off-line boilers: When heating demand can be met by just one boiler of a multiple-boiler installation, energy can be saved by isolating boilers not in use.
- Operate boilers efficiently: Examine operat-

ing procedures when more than one boiler is involved. It is far better to operate one boiler at 90% capacity than two at 45% capacity each. The more boilers used, the greater the waste of energy, not only by reduced boiler efficiency but by the operation of boiler auxiliaries.

• Adjust air/fuel ratios of firing equipment: the air-to-fuel ratio must be maintained properly. If there is insufficient air, the fire will smoke, cause tubes to become covered with soot and carbon, and thus lower heat transfer efficiency. If too much air is used, unused air is heated by combustion and exhausted up the stack, wasting energy.

• Check flue gas analysis on periodic basis: the efficient combustion of fuel in a boiler requires burner adjustment to achieve proper stack temperature, CO_2, and excess air settings. Check settings to provide stack temperatures of no more than 150°F above steam or water temperature, but sufficient to prevent SO_2 corrosion of equipment. There should be no carbon monoxide. For a gas-fired unit, CO_2 should be present at 9% or 10%; for No. 2 oil, 11.5% to 12.8%; for No. 6 oil, 13% to 13.8%.

• Reduce steam pressures and hot water temperatures: maintain the lowest possible steam pressures and hot water temperatures that meet space heat or process needs. Vary them in accordance with demand.

Chiller Plant

• Operate one of multiple compressors and chillers at full load, rather than two or more at partial loads.

• Improve operating efficiency by raising evaporator temperatures. To increase evaporator temperatures:

  • Raise supply air temperature.

  • Raise chilled water temperature.

  • Maintain full charge of refrigerant.

  • Maintain higher relative humidity levels in air conditioned space.

  • Refer also to general air handling and refrigeration equipment maintenance guidelines.

• Improve efficiency of chillers and compressors by lowering condensing temperatures. Measures to reduce condensing temperatures include:

  • Under light load conditions, when the refrigeration load is small and the ambient wet bulb temperature is likely to be low, the cooling performance of the tower will exceed the needs of the refrigeration machines. Under these conditions the cooling tower fan or fans can be cycled on and off to maintain a desired condenser water temperature, thus saving the horsepower required to drive the fans.

  • Adjust air flow and water rates to air cooled condensers and cooling towers to produce the lowest possible condensing temperature. Generally, the savings in refrigeration power will exceed any increase in added power for condenser fans or pumps.

  • Refer also to maintenance guidelines for cooling towers and condensers.

Refit

Boiler Plants

• Eliminate gas pilots and install electric pilots for boilers and furnaces.

• Install an economizer for preheating boiler feed water.

• Install soot blowers on all residual-oil burner systems. For new installation, select the size of multiple boiler installations so that they can be operated at 75% to 100% of rated capacity for both summer and winter load conditions.

• Add a blower and return air duct from occupied areas and convert gravity hot air furnace to forced warm air units.

• Modify piping as necessary to permit online boiler to maintain temperature in idle boilers rather than starting and stopping burner when the boiler is not needed to supply the load.

• Install automatic draft control to shut off the breaching 30 seconds after burners go off and restart automatically 30 seconds before next firing cycle to prevent heat loss up the chimney between firing cycles.

• Install additional condensate return lines to the boiler for feed water systems where uncontaminated condensate is being wasted. Where condensate is being wasted, consider installation of heat exchanger to preheat domestic hot water.

• Install and maintain proper steam regulators to reduce steam consumption. By-passes

should be used only during emergencies and during repair of regulators. On large installations, install flow meter and record changes so that an operator can analyze and maintain maximum efficiency.

- Install an interlock between combustion air unit and burner operating with proper prestart and after-firing control to reduce the amount of cold air introduced into the building for combustion.
- Install relief valves on hot water systems to vent air from the hot water piping.
- Install fan and duct, if necessary, to utilize warm air from the ceiling of the boiler or furnace room to preheat combustion air.
- Fit a "shell-head" adapter to the end of the gun of oil burners firing No. 2 oil to increase combustion efficiency.
- Regulate electric heating elements in steps or stages rather than full-on, full-off staging controls. Limit the demand on the electric supply system and eliminate wasteful override.
- For condensate pump systems, use heat exchangers to reclaim waste heat and reduce the temperature of the condensate and prevent cavitation in the condensate pump.
- Use automatic viscosity controls on fuel oil systems for purposes of attaining best atomization for efficient combustion. This control also permits flexibility of mixing and use of any grade fuel oil, either distillate or residual.
- Analyze loads and seasonal operating efficiency. Replace inefficient heating equipment with new modular-sized equipment to permit efficient operation at all partial load conditions.
- When replacing obsolete No. 6 oil burners, consider air atomization instead of steam atomization to improve performance and efficiency.
- Consider the recovery of heat or useful steam when blowing down the boiler.

Chiller Plants

- Raise evaporator temperatures and suction pressure.
- Isolate off-line chillers.
- Investigate repiping chillers in series if they are in parallel.
- When adding additional capacity for expansion and, where possible, in existing systems, use blow-through air handling units rather than draw-through.
- Install sensing control to raise supply air temperature when load permits. This will raise chilled water temperature and evaporator temperatures.
- Lower the condensing temperature.
- Modify exhaust ductwork to discharge cooled air from the building into the air intake of air-cooled condensers or cooling towers.
- Install sensing controls to permit cycling of cooling tower fans under light load conditions when refrigeration load is small and ambient wet bulb temperatures are low.
- Adjust fan blade pitch or fan speed of cooling towers for minimum power input.
- Install baffles in cooling towers and air-cooled condensers to reduce or eliminate by-pass of hot air around coils.
- Modify condenser water by-pass around cooling towers to reduce condenser water temperature to the lowest level compatible with the refrigeration machine.
- Replace air-cooled condensers with cooling towers.
- Fit capacity controls to existing refrigeration equipment where possible, and when replacing units, purchase those with four steps of capacity control.

Systems Convert

- Use well water, ground water, sea water, or lake water if the temperature of the water from these sources is lower than the wet bulb ambient temperature in the case of cooling towers and [illegible] dry bulb temperature in the case of condensers.
- Install controls to permit refrigerant migration on large systems to obtain refrigeration effect without power input to the chiller.
- Use piggyback absorption systems to produce additional chilled water when existing centrifugal chillers are driven by steam turbines.
- When replacing absorption refrigeration equipment, compare the performance of new, high-temperature absorption units with new, low-temperature, low-pressure, low-energy absorption units and select one based on best seasonal performance. (The former can be considered only where high-pressure boilers already exist. Where high-pressure boilers exist,

analyze turbine-driven equipment vs. absorption.)

• For expansion or modification, consider the use of standby diesel engines and generators or new, diesel-engine-driven refrigeration equipment to reduce electric loads. Consider using waste heat from the engines for other useful work.

• Convert straight compressors and chiller systems to heat pump operation by adding additional condensers and evaporators and/or repiping as required.

Distribution Systems

Refit

Hydronic Systems

• Install insulation on all hot and chilled water pipes, fittings, and valves passing through unconditioned spaces to minimize heat losses and heat gains.

• Replace fine-mesh strainer baskets with ones having the largest practical openings to reduce pressure losses.

• Remove orifice plates not regularly used for flow measurement.

• Balance hydronic systems to attain minimally satisfactory temperature and water flow.

• Trim impeller to actual size required on pump curve after terminal unit flows are reduced to the minimum. This will enable reductions of power requirements of actual load.

• Install flow measurement instrumentation. (Factory-assembled, pipe-mounted instrumentation can easily be cut into the system.)

• Check size of valves, filters, and pipe sections; replace undersized ones.

• Check all pipe fittings; replace inefficient ones.

• Consider adding a parallel small pump to handle heating load for dual-temperature changeover systems.

• Consider adding a variable-speed drive. Although this will conserve energy, it will limit the pump's ability to handle flow to the farthest terminal units.

Steam Systems

• Install insulation on all mains, risers, and condensate receiver tanks.

• Add additional shut-off valves for more efficient zone control.

• Install recorder pressure gauges and thermometers to enable continual monitoring of the system.

• Modify equipment as necessary to recover heat from condensate now going to the sewer. Such reclaimed heat can be used to heat a portion of the building or to preheat water being supplied to the domestic hot water heater or can be returned to the boilers.

Air Distribution Systems

• Test, adjust, and balance entire air distribution system in accordance with accepted practices.

• Insulate all ductwork carrying conditioned air through unoccupied spaces with at least 1½ inches of fibrous insulation or its thermal equivalent.

• Reduce system resistance to air flow to a minimum by replacing duct sections and fittings that impose unnecessary resistance on the system, replacing dirty filters with adequately sized filter media having high efficiency and low air flow resistance. Remove unnecessary dampers and other obstructions from ductwork and replace high-resistance inlets and outlets with modern grilles and diffusers providing low resistance.

• If air volume has been decreased to effect energy savings, determine resulting load on the fan motor. If it is less than 60% of name plate rating, consider replacing motor with a smaller one.

Electric Power

Quick Fix

General

• Through letters, memoranda, signs, personal communication, and other means, encourage building occupants to turn off all electrical equipment not in use, including portable fans, typewriters, calculators, coffee pots, etc.

• Disconnect all unnecessary devices. For example, ventilation fans can be turned off in elevators where smoking is not permitted.

• Turn off devices that are not being used. For example, vending machines (only those in which spoilage would not be a problem) and

drinking fountains can be turned off for the weekend. Consider time controls to do the job. It would be feasible to turn off such devices during the evening hours, also.

Power Transformers

- Shade exterior transformer banks from solar radiation to prevent heat build-up and resultant losses.
- Ventilate transformer banks to keep them as cool as possible.
- De-energize transformers whenever possible, including:
  - Unloaded transformers.
  - Transformers supplying unoccupied or unused spaces.
  - Refrigeration chiller transformer during the heating season.
  - Heating equipment transformers during the cooling season.
  - Heating and cooling transformers during periods of time that normally require no heating or cooling, as during spring and fall.

Outdoor Switchgear

- Provide shading.
- Remove or prune (in case of shrubbery) any obstructions that tend to diminish natural ventilation.

Refit

Demand Control and Power and Load Factor Improvement

- Peak shifting.
- Fuel substitution.
- Voltage level maintenance.

Automatic Controls

Refit

- Check operation of entire heating/cooling control system, including control valves and dampers. Correct all improper operations.
- Check control system for instrument calibration, set point, actuator travel and action, and proper sequence of operation.
- Inspect and calibrate pressure controls on dual duct system to obtain minimum static pressure during low demand. This will also reduce leakage.
- Adjust controls to prevent simultaneous operation of heating and cooling systems to achieve desired temperature.
- Limit the use of reheat to areas where humidity control is needed because of equipment needs. This can permit raising chilled water temperature.
- Add controls to allow 100% shutdown of air and water to unoccupied space.
- Inspect locations of thermostats. Relocate if they are currently positioned near outside walls, in areas that are seldom used, or if they are subject to outside drafts.
- Consider installation of key-lock plastic covers over thermostats to prevent building occupants from adjusting settings.
- Consider replacing pilots of gas-burning equipment with electric ignition devices.
- Install thermostats for control of all heating equipment.
- Consider installation of night set-back and morning start-up controls, which enable scheduling heating and cooling operations for each zone on the basis of occupancy patterns. A consultant may be required to determine when start-up should take place to insure comfort for occupants when they arrive for work.
- Consider installation of program clocks and manual overcall timers in control circuits to enable savings through scheduled operation of fans, refrigeration equipment, heating equipment, and so on. Additional economies may result from decreased costs of labor and maintenance.
- Consider adding an automatic draft damper control to reduce heat loss through breaching when the gas or oil burner is not in operation.
- Consider installation of automatic door closers on swinging doors leading to the exterior. Also consider such devices for garage and loading platform door operations.
- Consider adding time clocks on self-contained heating and cooling units for automatic shutoff.
- Consider adding a step-controller to electric heating systems with resistance elements to permit staging. This may result in more effective heat control and demand management.

Domestic Hot Water

Quick Fix

Reduce Domestic Hot Water Temperature

- Reduce generating and storage temperature levels to the minimum required for washing hands, usually about 100°F.
- Boost hot water temperature locally for kitchens and other areas where it is needed, rather than providing higher than necessary temperatures for the entire building.
- Encourage use of cold water detergents for laundries and laundromats and set water temperature to 70°F.
- Refer to health and food handling codes for minimum temperature specification for areas involving health or research services.

Reduce Quantity of Domestic Hot Water Used

- Adjust valves for minimum water use.
- Insert orifices in hot water pipes to reduce flows.
- Reexamine the need to heat an entire tank of water when only a small quantity of hot water is needed.
- Simplify menus to reduce the need for large pots and pans that require large amounts of hot water for cleaning. Where practical, use short dishwashing cycles and fill machine fully before use.
- Reduce the number of meals served and/or serve more cold meals to reduce the hot water requirements for dishwashing.
- In areas where water pressure is higher than a normal 40 to 50 pounds, restrict the amount of water that flows from the tap by installing pressure-reducing valves on the main service. Do not reduce pressure below that required for fire protection or for maintaining adequate pressure on the top floor for flushing.
- Refer to plumbing codes, if applicable, for hot water supply requirements.
- Encourage off-peak hot water use to reduce system energy demand.

Improve Efficiency of Storage and Distribution Systems

- Where forced circulation of hot water is used, shut off the pump when the building is unoccupied. When hot water usage is light, consider using gravity circulation without the pump.
- Flush water heater during seasonal maintenance of heating systems. Clean very thoroughly.
- Repair leaky faucets.
- Repack pump packing glands of recirculation hot water heaters to reduce leaking of hot water.
- For boilers with immersion, tankless, domestic hot water coils, make sure boiler water covers coils.

Refit

Reduce Consumption of Domestic Hot Water

- Reduce cold water pressure with an automatic control valve. Do not set lower pressure than needed for fire protection or to flush toilets on top floors.
- Install flow meters on cold water lines supplying the water heater when hot water consumption is more than 3,000 gallons per day.
- Install flow restrictors in the supply branch to groups of taps when existing faucets have flow rates greater than 1½ gpm.
- Install spray-type faucets that use only ¼ gpm instead of 2 or 3 gpm.
- Install self-closing faucets on hot water taps.
- For new additions, install foot-operated pedal valves.
- Replace obsolete kitchen equipment such as dishwashers with new ones that have minimal water requirements.
- Consider flow regulators in showers.

Reduce Temperature of Domestic Hot Water

- When the majority of domestic hot water use is at lower temperatures, install an electric, gas, or small oil-fired boiler to boost the temperature for kitchens, laundries, or processes requiring higher temperatures. Consult code authorities for minimum allowable temperatures for commercial kitchen use.
- Further reduce water heater temperatures during unoccupied periods such as shutdowns or vacations.

Reduce Thermal Loss from Hot Water Devices

- Insulate hot water storage tanks when insulation is less than the equivalent of 3-inch fiberglass and/or when insulation is in need of repair.
- Insulate hot water piping whenever there is less than the equivalent of 1-inch fiberglass.
- De-energize hot water circulating pumps to reduce heat loss from piping within the building. Where extremely long runs require that the circulator be in operation during occupied periods, install a seven-day timer to shut off the pump automatically during unoccupied periods.
- Insulate the exterior jacket of tankless or tank heaters that are not immersed in the hot water boiler or hot water tank.
- When installing new storage tanks or making major modifications to a building, relocate hot water tank as close to the load as possible.

Increase Efficiency of Hot Water Devices

- Replace gas pilots with electric ignition.
- Install local hot water heating units when domestic hot water usage points are concentrated in areas distant from the central generation and storage point.
- Repipe hot water storage tanks if the cold water make-up supply is connected to the upper half of the tank and/or if the hot water outlet from the tank is in the lower portion of the tank.
- Install a storage water heater for summer use when the existing space heating boiler is used for hot water generation.
- Replace electric hot water heaters with heat pumps to improve the coefficient of performance from 1 to approximately 3. Use hot drain water as a heat source for the heat pump, or use an air-to-water heat pump.
- When hot water demands are increased due to expansion or change in occupancy, provide either oil- or gas-fired water heaters or heat pumps rather than electric resistance heating. If the heating boiler has sufficient capacity and is in operation year-round for air conditioning, install a tank or tankless heater in place of a separate hot water generator. If the additional requirements for hot water are to serve facilities remote from the boiler, and usage is low, install a separate heater in the cold water line directly at the fixtures rather than serving them from a central system.

Elevators

Quick Fix

- Reduce the number of elevators in service during hours when the majority of persons are not leaving or entering the building.
- Turn off the motor-generator set located in the elevator machine room when not in use.
- Encourage occupants to walk up and down stairs instead of using the elevator.

Refit

- Install manual or automatic controls to disconnect elevators when they are not required.
- Connect elevators with manual or automatic load-shedding devices to reduce peak loads.
- Correct low power factor with capacitors or synchronous motors to reduce losses and to increase electrical distribution system capacity.
- Change oversized motors to improve the system power factor and motor efficiency.
- Utilize efficient dry-type transformers.
- Consider utilizing solid-state motor drives instead of motor-generator sets. Solid-state motor drives typically provide energy savings of from 25% to 30% as compared to motor-generator sets.
- Consider installation of demand-type elevator controls on elevators having through-trip or collective controls so elevators may be adjusted to insure that the least number of cabs travel the shortest distance.

Maintenance Procedures

Quick Fix

General

- Maintain log of maintenance and operation on all equipment.

Refrigeration and Control Equipment

- Inspect moisture-liquid indicator on a regular basis. If the color of the refrigerant indicates "wet," it means there is moisture in the system. This is a particularly critical problem because it can cause improper operation or costly damage. A mechanic should be called in to perform necessary adjustments and repairs immediately.

Also, if there are bubbles in the refrigerant flow as seen through the moisture-liquid indicator, it may indicate that the system is low in refrigerant. Add refrigerant if necessary.

- Use a leak detector to check for refrigerant and oil leaks around shaft seal, sight glasses, valve bonnets, flanges, flare connections, relief valve on the condenser assembly, and at pipe joints to equipment, valves, and instrumentation.
- Inspect equipment for any visual changes such as oil spots on connections or on the floor under equipment.
- Inspect the liquid line leaving the strainer. If it feels cooler than the liquid line entering the strainer, it is clogged. If it is very badly clogged, sweat or frost may be visible at the strainer outlet. Clean as required.
- Observe the noise made by the system. Any unusual sounds could indicate a problem. Determine cause and correct.
- Establish normal operating pressures and temperatures for the system. Check all gauges frequently to insure that design conditions are being met. Increased system pressure may be due to dirty condensers, which will decrease system efficiency. High discharge temperatures often are caused by defective or broken compressor valves.
- Inspect tension and alignment of all belts and adjust as necessary.
- Where applicable, lubricate motor bearings and all moving parts according to manufacturer's recommendations.
- Inspect insulation on suction and liquid lines. Repair as necessary.

Compressor (Centrifugal)

- Look for unusual compressor operation such as continuous running or frequent stopping and starting. Either may indicate inefficient operation. Determine the cause and, if necessary, correct.
- Observe the noise made by the compressor. If there seems to be excessive noise, it may be a sign of a loose drive coupling or excessive vibration. Tighten compressor and motor on the base. If noise persists, call a mechanic.
- Check all compressor joints for leakage. Seal as necessary.
- Inspect instrumentation frequently to insure that operating oil pressure and temperature agree with manufacturer's specifications.

Air Compressor

- Inspect all connections for air leaks, using a soap solution. Seal as necessary.
- Note operation. If compressor seems to run excessively, it could be a sign of pressure loss at the controls or somewhere in the piping system. Determine cause and correct.
- Inspect air pressure in supply tank and pressure regulator adjustment in supply line for proper limits.
- Check belt tension and alignment.
- Inspect air compressor intake filter pads and clean or replace as necessary.
- Lubricate electric motor bearings according to manufacturer's recommendations.

Air-Cooled Condenser

- Keep fan belt drive and motor properly aligned and lubricated.
- Inspect refrigeration piping connections to the condenser coil for tightness. Repair all leaks.
- Keep condenser coil face clean to permit proper air flow.
- Determine if hot air is being by-passed from the fan outlet to the coil inlet. If so, correct the problem.

Evaporative Condenser

- Inspect piping joints and seal all leaks.
- Remove all dirt from the coil surface by washing it down with high-velocity water jets or a nylon brush.
- Inspect air inlet screen, spray nozzle or water distribution holes, and pump screen. Clean as necessary.
- Use water treatment techniques if local water supply leaves surface deposits on the coil.
- Follow guidelines for fan and pump maintenance.

Water-Cooled Condenser

- Inspect condenser tubes annually or more often if experience proves it necessary.
- Clean condenser shell and tubes by swabbing with a suitable brush and flushing out with clean water. Chemical cleaning also is

possible, although it is suggested that a water treatment company be consulted first.

Cooling Towers

- Perform chemical testing of water to determine if solid concentrations are being maintained at an acceptable level. This should be done daily.
- Maintain draft eliminators in good condition to keep water loss at a minimum.
- Regulate water blowdown to the minimum consistent with water treatment and condition.
- Check overflow pipe clearance for proper operating level.
- Check fan by listening for any unusual noise or vibration. Inspect condition of V-belt. Align fan and motor as necessary.
- Follow guidelines for fan maintenance.
- Keep the tower clean to minimize both air and water pressure drop.
- Clean intake strainer.
- Determine if there is air by-pass from tower outlet back to inlet. If so, by-pass may be reduced through addition of baffles or higher discharge stacks.
- Inspect cooling towers for proper nozzle performance. Clean nozzles as necessary.
- Inspect gravity distributed tower for even water depth in distribution basins.

Chillers

- Chillers must be kept clean. Inspect on a regular basis, and clean as necessary.
- Inspect for evidence of clogging. A mechanic should be called in to service equipment in accordance with manufacturer's specifications.

Absorption Equipment

- Clean strainer and seal tank on a regular basis.
- Check unit vacuum regularly. If vacuum is low, there may be air in the unit.
- Check purge unit operation. Purge unit removes air and other noncondensing gases from machines. If purge operates continuously and vacuum is low, shut down and check for leaks.
- Check lithium bromide solution level regularly, add as needed, and maintain correct level.
- Monitor corrosion levels on lithium bromide side of the absorption machine to insure maximum heat transfer.
- Lubricate flow valves on a regular basis.
- Follow manufacturer's instructions for proper maintenance.

Self-Contained Units (Window and Through-the-Wall Units, etc.)

- Clean evaporator and condenser coils.
- Keep air intake louvers, filters, and controls clean.
- Keep air flow from units unrestricted.
- Caulk openings between unit and windows or wall frames.
- Check voltage. Full power voltage is essential for proper operation.
- Follow applicable guidelines suggested for compressor, air-cooled condenser, and fans.

Boilers (General)

- Keep a daily log of pressure, temperature, and other data obtained from instrumentation. This is the best method available to determine the need for tube and nozzle cleaning, pressure or linkage adjustments, and related measures. Variations from normal can be spotted quickly, enabling immediate action to avoid serious trouble. On an oil-fired unit, indications of problems include an oil pressure drop, which may indicate a plugged strainer, faulty regulating valve, or an air leak in the suction line. An oil temperature drop can indicate temperature control malfunction or a fouled heating element. On a gas-fired unit, a drop in gas pressure can indicate a drop in the gas supply pressure or a malfunctioning regulator.
- Inspect boilers for scale deposits, accumulation of sediment, or boiler compounds on water-side surfaces. Rear portion of the boiler must be checked because it is the area most susceptible to formation of scale. (Scale reduces the efficiency of the boiler and possibly can lead to overheating of furnace, cracking of tube ends, and other problems.)
- Fire-side of the furnace and tubes must be inspected for deposits of soot, fly ash, and slag. Fire-side refractory surface also must be observed. Soot on tubes decreases heat transfer and lowers efficiency. If gas outlet temperature rises above normal, it can mean that tubes need cleaning. Evidence of heavy sooting in short periods could be a signal of too much fuel and

not enough air. Adjustment of the air/fuel ratio is required to obtain clean-burning fire.

- Inspect door gaskets. Replace them if they do not provide a tight seal.
- Note firing rate when log entries are made. Realize that even a sharp rise in stack temperature does not necessarily mean poor combustion or fouled water-side or fire-side. During load change, stack temperatures can vary as much as 100°F in five minutes.
- Inspect stacks. They should be free of haze. If not, it probably indicates that a burner adjustment is necessary.
- Inspect linkages periodically for tightness. Adjust when slippage or jerky movements are observed.
- Observe the fire when the unit shuts down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace as necessary.
- Inspect and clean nozzles or cups on oil-fired burners on a regular basis.
- Check burner fan blades for collection of dirt. Clean as necessary.
- Check burner firing period. If it is improper, it could be a sign of faulty controls.
- Clean mineral or corrosion build-up on gas burners.
- Inspect all boiler insulation, refractory, brick-work, and boiler casing for hot spots and air leaks. Repair and seal as necessary.

Boilers (Fuel Oil)

- Check and repair oil leaks at pump glands, valves, or relief valves.
- Inspect oil line strainers. Replace if dirty.
- Inspect oil heaters to insure that oil temperatures are being maintained according to manufacturer's or oil supplier's recommendations.

Boilers (Coal-Fired)

- Inspect coal-fired stokers, grates, and controls for efficient operation. If ashes contain an excessive amount of unburned coal, it is probably a sign of inefficient operation or defective equipment.

Boilers (Electric)

- Inspect electrical contacts and working parts of relays and maintain in good working order.
- Check heater elements for cleanliness. Replace as necessary.
- Check controls for proper operation. Adjust as necessary.

Central Furnaces, Make-up Air Heaters, and Unit Heaters

- All heat exchanger surfaces should be kept clean. Check air-to-fuel ratio and adjust as necessary.
- Inspect burner couplings and linkages. Tighten and adjust as necessary.
- Inspect casing for air leaks and seal as necessary.
- Follow guidelines suggested for fan and motor maintenance.

Radiators, Convectors, and Baseboard and Finned-Tube Units

- Inspect for obstructions in front of the unit and remove whenever possible. Air movement in and out of convector unit must be unrestricted.
- Air will sometimes collect in the high points of hydronic units. It must be vented to enable hot water to circulate freely throughout the system, otherwise the units will short cycle (go on and off quickly), wasting fuel.
- Heat transfer surfaces of radiators, convectors, and baseboard and finned-tube units must be kept clean for efficient operation.

Electric Heating

- Keep heat transfer surfaces of all electric heating units clean and unobstructed.
- Keep air movement in and out of the units unobstructed.
- Inspect heating elements, controls, and, as applicable, fans on a periodic basis to insure proper functioning.
- As appropriate, check reflectors on infrared heaters for proper beam direction and cleanliness.
- Determine if electric heating equipment is operating at rated voltage, as necessary.
- Check controls for proper operation.

Humidification and Dehumidification Equipment

- Remove lint and dust periodically from air dampers, fan parts, spray chamber and diffuser, controls starter, and eliminator.

- Check equipment for carry-over. Carry-over may be maintained by adjusting eliminator seal gap, altering damper position, or changing air velocity.
- Follow guidelines suggested for fan and motor maintenance.

Air Handling Equipment

- Know proper fan speed and system pressure, volume, and temperature conditions. Make daily checks to maintain these conditions.
- Inspect ductwork for air leakage. Seal all leaks by taping or caulking.
- Inspect ductwork insulation. Repair or replace as necessary.
- Utilize ductwork access openings to check for any obstructions such as loose-hanging insulation (in lined ducts), loose-turning vanes and accessories, and closed fire dampers. Adjust, repair, or replace as necessary.
- Inspect damper blades and linkages. Clean, oil, and adjust them on a regular basis.
- Inspect air valves in dual duct mixing boxes to insure full sealing and minimum air leakage.
- Inspect mixing dampers for proper operation. Adjust as necessary.
- Clean or replace air filters on a regular basis. Maintain pressure drop across filters within preselected limits.
- Inspect air heating, cooling, and dehumidification coils for cleanliness. Coils must be kept clean by using a mixture of detergent and water in a high-pressure (500 psig) portable cleaning unit.
- Inspect for leakage around coils or out of the casing. Seal all leaks.
- Inspect all room air outlets and inlets (diffusers, registers, and grilles). They should be kept clean and free of all dirt and obstructions. Clean and remove obstructions as necessary.
- Inspect air washers and evaporative air cooling equipment for proper operation. Clean damper blades and linkages if so equipped. Inspect nozzles and clean as necessary.
- If electronic air cleaners are installed, check them regularly for excessive accumulations on the ionizing and grounding plate section. Replace filter media if necessary. Follow manufacturer's written instructions whenever adjustment or maintenance is required.
- Inspect humidifier/dehumidifier air dampers, fan parts, spray chamber, diffuser, controls, strainer, and eliminator. All must be kept free of dirt, lint, and other foreign particles. Clean eliminator wheel by directing a high-pressure stream of water between blades.
- Adjust all VAV (variable air volume) boxes so they operate precisely. This will prevent overheating or overcooling, both of which waste energy.
- Follow guidelines suggested for fan maintenance.

Motors

- Check alignment between motors and equipment. Align and tighten as necessary.
- Check for loose connections and bad contacts on a regular basis. Correct as necessary.
- Keep motors clean.
- Eliminate excessive vibrations.
- Lubricate motor and drive bearings on a regular basis. This will help reduce friction and excessive torque, which can result in overheating and power loss.
- Replace worn bearings.
- Tighten belts and pulleys.
- Check for overheating, which could indicate a functional problem or lack of adequate ventilation.
- Balance three-phase power sources to motors. An imbalance can create inefficient motor operation and use more energy.
- Check for over-voltage or low voltage condition on motors. Correct as necessary.

Engines

- Follow manufacturer's recommended maintenance procedure.
- Check fuel consumption and compare with design fuel consumption.
- Record and check cooling water temperatures daily. If cooling water temperatures exceed manufacturer's recommendations, check temperature controls and correct as necessary.

Turbines

- Follow manufacturer's recommended maintenance procedures.
- Record steam pressure and check speed daily.
- Check oil level, packing leakage, governor, and throttle valve operation regularly.

- Record and check bearing temperatures.
- Record and check oil cooler temperatures.
- Check vibrations weekly.

Fans

- Check for excessive noise and vibration. Determine cause and correct.
- Keep fan blades clean.
- Inspect and lubricate bearings regularly.
- Inspect drive belts. Adjust or replace to insure proper operation. Proper tensioning of belts is critical.
- Inspect inlet and discharge screens on fans. They should be kept free of dirt and debris at all times.
- Inspect fans for normal operation.

Pumps

- Check for packing wear, which can cause excessive leakage. Repack to avoid water wastage and shaft erosion.
- Inspect bearings and drive belts for wear and binding. Adjust, repair, or replace as necessary.

Hot and Chilled Water Piping

- Check for leakage at joints.
- Check flow measurement instrumentation for accuracy. Adjust, repair, or replace as necessary.
- Inspect insulation of hot and chilled water pipes. Repair or replace as necessary. Be certain to replace any insulation damaged by water. Determine source of water leakage and correct.
- Inspect strainers. Clean regularly.
- Inspect heating and cooling heat exchangers. Large temperature differences may be an indication of air binding, clogged strainers, or excessive amounts of scale. Determine cause of condition and correct.
- Inspect vents and remove all clogs. Clogged vents retard efficient air elimination and reduce efficiency of the system.
- Use water treatment to insure that internal surfaces are kept clean to maintain maximum rate of heat transfer.

Steam Piping

- Inspect insulation of all mains, risers and branches, economizers, and condensate receiver tanks. Repair or replace as necessary.
- Check automatic temperature-control system and related control valves and accessory equipment to insure that they are regulating properly in various zones—in terms of building heating needs, not system capacity.
- Inspect zone shut-off valves. All should be operable so steam going into unoccupied spaces can be shut off.
- Inspect steam traps. Their failure to operate correctly can have a significant impact on the overall efficiency and energy consumption of the system. Several different tests can be utilized to determine operations:
  - Listen to the trap to determine if it is opening and closing when it should.
  - Feel the pipe on the downstream side of the trap. If it is excessively hot, the trap probably is passing steam. This can be caused by dirt in the trap, valve off stem, excessive steam pressure, or worn trap parts (especially valve and seats). If it is moderately hot—as hot as a hot water pipe, for example—it probably is passing condensate, which it should do. If it is cold, the trap is not working at all.
  - Check back-pressure on downstream side.
  - Measure temperature of return lines with a surface pyrometer. Measure temperature drop across the trap. Lack of drop indicates steam blow-through. Excessive drop indicates that the trap is not passing condensate. Adjust, repair, or replace all faulty traps.
- Inspect all pressure-reducing and regulating valves and related equipment. Adjust, repair, or replace as necessary.
- Inspect condensate tank vents. Plumes of steam are an indication of one or more defective traps. Determine which traps are defective and adjust, repair, or replace as necessary.
- Check accuracy of recording pressure gauges and thermometers.
- Inspect pump for satisfactory operation, looking particularly for leakage at the packing glands.
- Correct sluggish or uneven circulation of steam. It usually is caused by inadequate drainage, improper venting, inadequate piping, or faulty traps and other accessory equipment.
- Correct any excessive noise to provide more efficient heating and to prevent fittings from being ruptured by water hammer.

• Check vacuum return system for leaks. Air drawn into the system causes unnecessary pump operation, induces corrosion, and causes the entire system to be less efficient.

Water

Quick Fix

• Turn off laboratory and other water-consuming equipment when not in use.

• Inspect water supply system and repair all leaks.

• Check closely for percentage of make-up water in power plants. Monitor boilers for make-up water; investigate changes of 5% or more.

• Check pump packing glands for excess leakage. Repair as necessary.

• Adjust the rate of bleed-off from cooling towers according to water test results.

• Regularly calibrate instruments that automatically control the bleed-off rate.

• Improper sprinkling of shrubbery and lawns can waste water. Consult local nurseries for proper procedure, frequency, time of day, and amount of watering necessary.

• Flow of apparently clean water into drains should be investigated. Consider reusing this water.

• Where practical, disconnect refrigerated water fountains.

• Consider replacing free-running drinking fountains with spigot types that utilize paper cups. Up to half the water drawn by free-running fountains is wasted.

Food Service Areas

Quick Fix

• Turn off infrared food warmers when no food is being warmed.

• Inspect refrigeration condensers routinely to insure that they have sufficient air circulation and that dust is cleaned off coils.

• Inspect and repair walk-in or reach-in refrigerated area doors without automatic closers or tight gaskets.

• Train employees in conservation of hot water. Supervise their performance and provide additional instruction and supervision as necessary.

• Avoid using fresh hot or warm water for dish scraping.

• Keep refrigeration coils free of frost build-up.

• Clean and maintain refrigeration equipment on water chillers and cold-drink dispensers.

• Reduce temperature of or turn off frying tables and coffee urns during off-peak periods.

• Preheat ovens only for baked goods. Discourage preheating any sooner than necessary.

• Run dishwasher only when it is filled.

• Cook with lids in place on pots and kettles, which can reduce heat requirements by half.

• Thaw frozen foods in refrigerated compartments.

• Fans that cool workers should be directed so they do not cool cooking equipment.

• Consider using microwave ovens for thawing and fast-food preparation whenever they can serve to reduce power requirements.

Space Utilization

General

• Based on an energy audit, determine which buildings are most energy-efficient; which areas of each building are least expensive to illuminate, heat, cool, and ventilate during different seasons and during different hours of the day. Encourage greatest reliance on the most energy-efficient buildings during seasons when maximum energy efficiency is achieved and during times of day when maximum efficiency occurs.

• Consolidate evening classes and extracurricular activities into as few buildings as possible or into as few zones in a given building as possible.

• Schedule classroom use on a campus-wide basis rather than by department so that greatest reliance is placed on the most energy-efficient facilities.

• Students should not be permitted to use idle classrooms indiscriminately as study halls. Alternate facilities should be provided.

• Schedule building use to avoid peak demand hours.

• Close dormitories and other applicable buildings during vacations.

• Develop an emergency energy curtailment space utilization plan in the event of serious energy shortages.

Emergency Space Consolidation

• Close down all nonessential buildings such as heated storage areas.

• Close off portions of academic buildings, where feasible, by increasing classroom utilization in other areas of the buildings.

• Close down buildings or portions thereof that are used strictly for social events.

• Combine use of duplicate facilities (theaters, lecture halls, and athletic facilities).

• Eliminate third shift (midnight to 8 a.m.) work activities to the extent possible without impairing safety and security.

• Close down entire classroom buildings through joint use of buildings with other departments.

• Discontinue extracurricular activities that are not an integral part of the education process.

• Minimize the number of classroom buildings used during exam periods.

• Obtain, if feasible, joint use of athletic facilities with other nearby institutions.

• Close down all but primary food service facilities.

• Combine some primary food service facilities; maintain those that are most economical from an energy conservation standpoint.

• Consolidate administrative facilities; close down entire buildings where feasible.

• Discontinue administrative activities that will not impair safety, etc.

• Consolidate student housing facilities; close down entire buildings where feasible.

• Extend vacations into reading periods.

• Cancel special alumni and similar group activities that require housing and food service.

• Reduce activities to avoid periods of temperature extremes.

• Extend academic year beyond normal closing date to make up for any time lost during normal year.

Transportation

General

• Establish and enforce a maximum speed for all institutionally owned vehicles.

• Replace standard-size vehicles with smaller cars wherever possible.

• Organize a car pool with central coordination by campus volunteers or paid staff.

• Adjust carburetors for leanest fuel mixture.

• Keep engines in fine tune through regular preventive maintenance.

• Urge departments or schools to consolidate local trips for package pickup system if volume warrants.

• Consolidate field trips.

• Eliminate all motor pool practices except medical, police, and maintenance.

• Charge reduced parking fees for persons in car pools.

• Encourage use of campus bus system.

• Prohibit anyone living within a certain distance from the campus from parking on campus.

• Start *Wednesdays-are-for-walking* or other, similar programs.

• Put "Conserve Fuel" stickers on automobile dashboards.

• Explore use of three-wheel motor carts or electric or propane vehicles for physical plant personnel. (The U.S. Postal Service may have surplus vehicles for sale.)

• Follow octane requirements specified in vehicle manuals. Higher octane than specified is inefficient.

• Make sure tires are inflated to manufacturer's specifications and that wheels are aligned.

• Do not leave vehicle idling while making pickup or delivery calls.

• Encourage drivers to avoid sudden starts and stops.

• Reduce services requiring gasoline-powered vehicles.

Appendix C

REPORT TO

IMPLEMENT ENERGY CONSERVATION MEASURES

AT

HITCHCOCK HALL

The Ohio State University

Environmental Control Group

Department of Mechanical Engineering

Columbus, Ohio 43210

Submitted by:
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September 16, 1975

Introduction

Electrical energy use history of the building was obtained from metering records. Metered data was not available for the steam used; however, annual steam usage was approximated by analysis of loads, weather conditions, and present system operation.

Energy conservation techniques were applied to the facility, and determination of their effects was established by a mathematical investigation. This report briefly discusses recommended energy conserving measures, their respective implementation costs, and return on investment considerations.

The following energy conservation measures are discussed in this report:

Item No. 1: Effect on Energy Consumption for Unoccupied Cycles of Operation on Several of the Air Handling Systems

Item No. 2: Effect on Energy Consumption for Reduced Lighting and Air Volume Level (with Unoccupied Cycle of Operation Assumed implemented)

Item No. 3: Effect on Energy Consumption for Conversion of the Constant Volume Reheat Systems to Variable Volume Reheat Systems (with Unoccupied Cycle of Operation Assumed implemented)

Item No. 4: Effect on Energy Consumption for Instituting the Economizer Cycle of Operation for AH-2 and AH-3.

The collective effect on energy consumption upon implementation of all of the system modifications was also examined. Reduction of peak lighting load (due to the removal of fluorescent tubes) affects variable air volume savings, so that the collective energy savings are not additive.

TABLE 1

HITCHCOCK HALL

EFFECT ON ENERGY CONSUMPTION FOR SYSTEM MODIFICATIONS

Gross Area: 119,671 sq. ft. Supply Air: 141,175 cfm CFM/SQ.FT.: 1.18 Original B/SQ.FT./YR: 458,368 Revised B/SQ.FT/YR: 204,313	Base	Item #1	Item #2	Item #3	Item #4	Item #5
	Past Energy Use (1)	Unoccupied Cycle of Operation for Several Air Handlers	Reduced Lighting & Air Flow for Several Air Handlers (2)	Conversion of the Constant Volume Reheat Systems to Variable Volume Reheat Systems (2)	Institute Economizer Cycle of Operation for AH-2 and AH-3 (2)	Sum Effect of All Modifications
Electrical Consumption (1000's kwh)	2,887	2,295	1,740	2,230	2,295	1,720
Equivalent Gas Consumption (mcf)	45,000	26,540	23,755	23,675	2[illegible],540	18,580
Cost of Energy (Dollars) (3)	114,420	78,560	64,420	73,495	72,440	57,130
% Dollar Reduction for Modification	--	31	12	4	5	50
Savings in Energy Costs (Dollars)	--	35,860	14,140	5,065	6,120	57,290
Estimated Implementation Cost (Dollars)	--	19,500(4)	15,240	17,980	8,400	55,240(4)
Return on Investment (months)	--	6	13	42	16	12

(1) Electrical usage was determined from accurate metering records. Gas usage was estimated from analysis of load and weather conditions. 4% electrical line losses were added to the metered consumption.
(2) Unoccupied Cycle has been assumed implemented. Savings represent those beyond unoccupied cycle savings.
(3) Costs of gas and electricity used were June, 1975, utility rates: 1.87 cents per kwh for electricity and $1.34 per mcf.
(4) This cost can be reduced by $10,000 due to partial accomplishment through Phase I of C.C.E.C.C. project.

The effects of the proposed conservation measures on the total consumption of energy are summarized in Table 1. The reader is requested to refer to Table 1 for the following discussions of the modifications.

Item No. 1: Effect on Energy Consumption for Unoccupied Cycles of Operation on Several of the Air Handling Systems.

a) The facility is normally used Monday through Friday between 8:00 a.m. and 11:00 p.m. Evening usage is generally confined to the auditorium or large lecture rooms; both areas are served by one air handler, AH-1.

b) When completed, unoccupied operation for AH-1 will be as follows: Shutdown of the main fans (SF-1, RF-1), exhaust fans (EF-D, E, H), and circulating pumps will be accomplished through sequencing of a time clock. Shutdown will occur at 11:00 p.m. Monday through Friday, and the system will restart at 7:00 a.m. on weekdays. A low limit thermostat will cycle the system on upon demand during the winter season. A manual override will be located in the mechanical room to accommodate occasional weekend use of the auditorium and lecture rooms. It should be noted that AH-1 was inoperative this past summer. This practice may not continue in the future, if usage of the auditorium varies. Reported savings reflect a normal unoccupied cycle of operation; if AH-1 remains off in the summer quarters, a greater savings will be realized.

c) When completed, unoccupied operation for AH-2 and AH-3 will also be controlled by time clocks providing sequenced shutdown of the main fans (SF-2, RF-2, SF-3, RF-3), exhaust fans (EF-F, G, I, J), and circulating pumps. Shutdown schedule is as follows: System will be inoperative at 5:00 p.m. Monday through Friday and will come back on line at 7:00 a.m. weekdays. A low limit thermostat will restart air handling system(s) upon demand during the winter season.

d) The lab area unit (AH-4) will be shutdown during the same hours as those listed in (b) by the clock control. A manual override will be installed to be used in the event of necessary experimental work during usual unoccupied hours. Lab area supply fan, and EF-A, B and C will be shut down during unoccupied operation.

e) The two direct expansion units will be shutdown at 11:00 p.m. Monday through Thursday, and 5:00 p.m. on Friday by time clock control. The units will restart at 7:00 a.m. weekdays. The shutdown schedule is coordinated with present computer usage. Variance in the future can be handled by simple adjustment in the time clock control.

f) The primary pumps will be shutdown when all of the air handlers go off by the use of relays. The pumps will sequence on when any air handler comes on line for either low limit or occupied operation.

g) Table I reveals a total energy savings of $35,860 at an estimated cost of $19,500 for a return on investment in 6 months. Much of this will be accomplished by the Central Campus Environmental Control Center Contract, reducing the actual funds required for implementation to $9,500.

Item No. 2: Effect on Energy Consumption for Reduced Lighting and Volume Levels for Several Air Handlers.

a) A total of 4342 tubes will be removed from the building. This reduction in lighting level allows a smaller air flow volume due to reduced cooling load. Savings are reflected in cooling costs, fan operating costs, and lighting costs.

b) Reduced lighting level and air flow volume will be accomplished at a total cost of $15,240 and will save an additional $14,140 beyond unoccupied cycle savings, yielding a return on investment in 13 months.

Item No. 3: Effect on Energy Consumption for Conversion of the Constant Volume Reheat Systems to Variable Volume Reheat Systems.

a) Many areas of the facility operate at maximum occupancy for only a few hours a week so that supply air volume can be varied at other times to reflect the load. As an example,

the large First Floor auditorium (Room 131) is used as a lecture room for only a few hours per day, and for assembly a few evenings a week. At other times, the room is generally unoccupied, and the load is small. In the latter situation, the zones can supply a smaller air flow, leading to reduced cooling load, reduced reheat load, and reduced fan load for considerable energy savings.

b) Motor operated volume dampers will be installed for AH-1, on terminal units controlled with the reheat coil valves to vary supply air volume. Minimum air quantity requirements will be maintained so that proper ventilation is ensured.

c) Large classrooms on the second, third, and fourth floors are typically supplied through four mixing boxes; two are located near a room's exterior exposure, while the other two serve the interior portion. A sheet metal blank-off will be installed on the hot deck connection of the interior boxes, allowing only variable volume cooling through these boxes. This conversion to partial variable volume will reduce false loading of the systems and permit reductions in fan loads to obtain savings in both electrical and steam consumption.

d) Table I shows the systems can be partially converted to variable volume for an estimated implementation cost of $17,980. The measure provides annual energy savings of $5,065, for a return on investment in 42 months.

Item No. 4: Effect on Energy Consumption for Instituting the Economizer Cycle of Operation for AH-2 and AH-3

a) In the past, building pressure problems have not allowed successful economizer cycle of operation. Changeover to minimum outside air has been at a point lower than optimum, so that mechanical cooling was required even in moderately cold weather.

b) Outside air, return, and relief dampers will be replaced with low leakage dampers. The present birdscreen (1/4" mesh) on the outside

air intake of AH-3 will be replaced with 3/4" hardware cloth. The expanded metal screen on the relief dampers of AH-2 will also be removed. One of the three sections of the outside air intake of AH-2 will be blanked off to reduce outside air intake area to its proper size. The above measures along with reduced air volume should help resolve the pressure problems and allow successful economizer cycle operation, with changeover point at 70°F.

c) Table I shows successful economizer operation will save $6,120 in annual operating costs at an estimated implementation cost of $8 400, for a return on investment in 16 months.

Detailed Cost Estimates for Implementing Conservation Measures

Modification 1 - Unoccupied

AH-1
Shutdown SF-1, RF-1, EF-D, EF-E, circ pumps

Time clock	$ 400.00	
Controls & wiring	1,200.00	
Override control	100.00	
2 low limit thermostats	500.00	
		$ 2,200.00

AH-2 & AH-3
Shutdown SF-2, RF-2, EF-1, EF-J, circ pumps, SF-3, RF-3, EF-F, circ pumps

2 time clocks	$ 800.00	
Controls & wiring	2,400.00	
4 low limit thermostats	1,000.00	
		$ 4,200.00

AH-4 (Lab Area)
Shutdown SF-4, EF-A, B, C, circ pumps

Time clock	$ 400.00	
Controls & wiring	1,400.00	
Override control	100.00	
		$ 1,900.00

DX-5 & DX-6 (Computer Area)

Time clock	$ 400.00	
Controls & wiring	1,000.00	
Override control	100.00	
		$ 1,500.00

Chilled & Heating Hot Water Systems
Shutdown at night after AH systems are off

Controls & wiring	$ 3,500.00
4 Ventilation Overrides @ $1,000.00	$ 4,000.00
Engineering & Contingencies	$ 2,200.00
TOTAL	$19,500.00

Modification 2: Reduced L & V

4342 tubes removed @$1.00/tube	$4,342.00	
New Fan Drives		
3 S.A. Fans @$800.00	2,400.00	
3 R.A. Fans @$700.00	2,100.00	
Rebalance Mixing Boxes & Zone Dampers		
10 zone dampers @$90.00	900.00	
150 mixing boxes @$30.00	4,500.00	
Engineering & Contingencies	998.00	
TOTAL		$15,240.00

Modification 3: VAV

New Fan Drives		
3 S.A. Fans @$800.00	$2,400.00	
3 R.A. Fans @$700.00	2,100.00	
Blank off plates		
66 Mixing Boxes @$30.00	1,980.00	
Motorized Volume Dampers @$500.00	5,000.00	
Motor operators & controls for inlet vanes		
3 S.A. & R.A. Fans	4,500.00	
Engineering & Contingencies	2,000.00	
TOTAL		$17,980.00

Modification 4: Economizer Cycle

Install New Low Leakage Dampers on AH-2 System

a. O.A. Damper Return Damper Relief Damper	$1,000.00	
b. Labor to remove old dampers and install new dampers-birdscreen blank-off	1,000.00	
c. Provide 3 additional damper operators and install baffle on return fan discharge side.	500.00	
d. Engineering & Contingencies	1,000.00	
	$3,500.00	

Install New Low Leakage Dampers on AH-3 System

a.	O.A. Damper Return Damper Relief Damper	$1,500.00	
b.	Labor to remove old dampers and install new dampers to include replacement of birdscreen	1,200.00	
c.	Re-locate outside sensor	200.00	
	3-damper operators	500.00	
d.	Engineering & Contingencies	1,500.00	
		$4,900.00	
TOTAL			$ 8,400.00

TOTAL COST

Modification No. 1		$19,500.00
Modification No. 2		15,240.00
Modification No. 3		17,980.00
Less fan drives furnished in #2	$3,000.00	
Less rebalance in #2 not required		
66 Mixing boxes @$30.00	1,980.00	
10 zone dampers @$90.00	900.00	
		(5,880.00)
Modification No. 4		8,400.00
		$55,240.00
Part of Modification No. 1 will be accomplished through Central Campus Energy Control Center Contract PHASE I.		($10,000.00)
TOTAL		$45,240.00

DESCRIPTION OF EXISTING SYSTEMS

Hitchcock Hall is a four story structure with a full basement, housing offices, classrooms, laboratories, auditoriums, and a computer facility. The building is served by two double duct high velocity reheat systems, one multizone reheat system, one single duct reheat system, and two direct expansion units (for the computer areas). The total air delivery is 141,175 CFM to a gross area is 119,671 square feet, yielding 1.18 CFM per square foot.

Steam is delivered to the structure through the central steam distribution system of the University's Power Plant, and is used for both heating and cooling. Two steam absorption chillers with an installed capacity of 400 tons each provide cooling. The two direct expansion units are electric reciprocating units with an installed capacity of 10 tons each.

Yale University *New Haven, Connecticut 06510*

Appendix D-1

Office of the President

November 28, 1973

MEMORANDUM

TO: The Yale Community

FROM: Kingman Brewster, Jr.

RE: Energy Conservation

The officers of the University, together with the Dean of Yale College, the Acting Dean of the Graduate School and the Chairman of the Council of Masters have considered a variety of energy conservation measures for Yale University. The purpose of this communication is to inform the University Community of Yale's present position, to announce further conservation measures, and to initiate contingency planning in case of severe fuel shortages.

The Director of Operations has assured me that Yale's present fuel supply position is stable, although possible state or federal allocation plans could cause Yale a fuel shortage. In view of the uncertainty of fuel supply and governmental policy with respect to rationing, it seems prudent to undertake voluntary energy conservation measures throughout the University. We have considered and rejected a calendar modification which would have shut Yale down until the first week in February. However, we believe the national energy crisis is serious enough to require other measures outlined below which will entail some inconvenience to members of the Yale Community.

Additional energy savings will not be easy because Yale has already initiated an energy conservation program which has eliminated many of the obvious sources of energy waste. The cumulative effect of such measures, including better control of mechanical systems, lowering of temperatures, etc., yielded $300,000 of savings in 1972/73 alone (about 8% energy reduction). Yale's energy conservation efforts are complicated by the concentration of consumption in relatively few buildings, mainly in the Science Complex and the Medical School, where sensitive on-going experiments require constant climate control. For example, the Kline Biology Tower and the Sterling Chemistry Lab alone equal the annual energy consumption of all of Yale's residential colleges. Consequently, there are not many obvious ways to save significant amounts of energy short of a near total suspension of major sectors of the University's activity. There are, however, several less drastic measures which, in the aggregate, will enable Yale to achieve at least a 5% energy consumption reduction at once.

1. There will be a further reduction in the average room temperature in Yale buildings. A target of 68° has been set. The policy of reducing heat to buildings at the end of normal working hours and during weekends will remain in effect. Yale's central heating system has antiquated controls, which makes it difficult to achieve acceptable temperatures at the extremity of a steam line without overheating locations near the source. However, some pockets of overheating can be

eliminated through localized valve and radiator adjustments. A special office to handle overheating reports has been established at 20 Ashmun Street. Instances of overheating should be reported to Ext. 24146.

2. The University will suspend normal operations insofar as possible during the period December 22, 1973 through January 1, 1974. Employees whose offices are shut down would be expected to count the time off as their normal Christmas vacation. Bargaining Unit employees may elect to count the time off against floating holidays and/or available vacation days. The residential colleges and all other undergraduate dormitories will remain closed until January 12, 1974. Students will not be allowed to reside in their rooms during that period. Heat will be reduced in all buildings affected by the shutdown to 50° and hot water service will be suspended. Masters', Deans' and Resident Fellows' apartments will be heated through localized units. It is estimated that this action will save over 325,000 gallons of fuel. A building-by-building schedule will be issued later this week. However, Science and Medical School buildings containing on-going research, the Health Center, the main Library and certain essential administrative offices will remain open. The Hall of Graduate Studies, Helen Hadley Hall and the Medical School dormitories will remain open. A few dormitory spaces in Ray Tompkins House will be available for undergraduates, especially those from foreign countries, who are not able to return home for Christmas. Applications for such space should be made to the Yale College Dean's Office.

3. I have asked the Acting Director of Personnel to review the possibility of a change in working hours to take full advantage of daylight hours. The normal work schedule might be from 8:00 A.M. to 4:00 P.M., with one-half hour for lunch (8:30 A.M. to 4:30 P.M. if Daylight Savings is restored).

4. I have asked the Secretary of the University to consolidate in as few buildings as possible all public and extracurricular events occurring on weekends and in the evening.

5. I have asked that a specific energy conservation plan be developed for each building by the Engineering Section of Buildings & Grounds Service and that an energy monitor be appointed on a building-by-building basis. This plan should include considerations of temperature, schedule of use, illumination levels and tighter control of mechanical systems.

6. I have asked the Chief of the Campus Police to review external illumination for the purpose of reducing it consistent with safety requirements. Decorative lighting of buildings, such as Harkness Tower, has been eliminated. No external Christmas decorations requiring energy will be erected this year.

7. I have asked the Department of Buildings & Grounds Services to review all designs of new and renovated buildings to minimize energy consuming features of such designs. There will be a presumption against comfort air conditioning in new buildings or major renovation requests. I have asked for a review of comfort air conditioning throughout the University for the purpose of shutting down or severely restricting the operation of all units.

8. I am appointing a Faculty Energy Conservation Advisory Committee to work with the Director of Operations in exploring further possible

conservation measures, especially in high energy consuming buildings in the Science and Medical areas. The Committee will consist of:

Charles K. Bockelman
Elias Clark
Radley H. Daly
Georges May
Merton J. Peck
Frederic M. Richards
George Veronis

Members of the Yale Community are invited to bring suggestions to the attention of members of this Committee.

The energy crisis is not likely to pass quickly or quietly from our lives. While no one can predict with certainty what fuel shortages will mean for our accustomed way of life this winter or beyond, it seems likely that more fundamental alterations in our patterns of work study and recreation are in prospect. Consequently, I have asked the Director of Operations, in consultation with the Advisory Committee, to prepare contingency plans for fuel shortages based on 10-20-30% of present consumption. The Officers and Deans are directed to explore the costs and benefits of a major calendar revision for the 1974/75 school year which would close the University from before Christmas to early February. Such a calendar change may represent the only feasible remaining source of energy savings after the measures outlined in this memorandum have been implemented.

Many of the specific proposal suggested here for energy conservation depend on the thoughtful cooperation of all members of the Yale Community. I hope the cumulative effect of those measures will spare Yale more fundamental dislocations.

KBJr:chs

Appendix D-2

May 6, 1974

Memorandum

To: Deans, Directors, and Department Chairmen

From: The Officers of the University

Subject: Air Conditioning Policy

In view of the national energy shortage, the university has reexamined its policy with respect to air conditioning. In his memorandum of November 28th, the President asked for such a review because air conditioning at the university consumes a significant amount of annual energy. For example, a typical window unit (one-ton capacity) running normally for a season consumes 1,100 kilowatt hours of electrical energy. A one-ton capacity air conditioning unit operating from a central chilled water plant uses 2.5 barrels of fuel oil in the same period. Consequently, significant energy savings can be achieved by a moratorium on the installation of new air conditioning and a curtailment of existing service.

The current uncertainty about the availability and price of energy makes it difficult to establish an air conditioning policy which neither underestimates nor over-reacts to possible future energy shortages. Therefore the officers of the university in consultation with the Faculty Energy Conservation Advisory Committee have developed an interim air conditioning policy, to take effect immediately.

A. Installation of New Air Conditioning

1. There will be a moratorium on the installation of new window units or other localized air conditioning. Requests for exceptions to this policy in order to accommodate the installation of temperature sensitive equipment where necessary in research space or for gallery, library, and museum collections or other extenuating circumstances must be approved by the Faculty Energy Conservation Advisory Committee.

2. Plans for new construction or major renovations henceforth will be reviewed from an energy savings standpoint by the Office of Buildings and Grounds Services. The university's Engineering Department is developing a detailed memorandum on energy savings considerations which will be furnished to architects of new buildings and major renovations. Since the heating and cooling functions are intertwined in almost all modern buildings, new construction will have the capacity for air conditioning. However, the decision to activate air conditioning service in a new building will depend on the energy circumstances which prevail when a new building becomes available for occupancy.

B. Curtailment of Existing Service - Policy Guidelines

1. The university has considered a variety of measures for the curtailment of present air conditioning service. These considerations address the widely varying circumstances within the university which make a uniform and mandatory policy difficult to develop. Some buildings work from central controls while other offices are cooled by individual

units. Some work essential to research or daily university operations must be conducted at a specific location, while other activities could be moved to air-conditioned locations such as the Cross Campus Library. Temperature-humidity ranges vary widely from building to building depending on the type of construction or the equipment contained in the building. Some sensitive equipment and research projects require more carefully controlled temperature ranges than others.

In view of these variations, the university has elected a policy of voluntary compliance with the guidelines outlined below:

a. Local air conditioning units should not be used until temperatures during working hours reach 80° in a particular location.

b. Buildings with centrally controlled air conditioning will operate at a temperature of about 80° during working hours. Those buildings now operate in the summer closer to 70°. Consequently, the new target temperature will mean an increase of 8 or 9°.

c. After normal working hours and on weekends, air conditioning should be turned off regardless of the temperature except in centrally air conditioned buildings where the temperature range would be 80-85°.

2. Exceptions to Policy

Sensitive equipment or certain research projects may require exceptions to the presumptions outlined above. Requests for exceptions should be submitted to the Manager of Engineering, Buildings and Grounds Services, who will forward them to the Faculty Energy Conservation Advisory Committee for review. Such requests for exception should be submitted by the Departmental Chairman or by other appropriate budgetary unit authority.

C. Temperature Sensitive Equipment

Energy shortages in the foreseeable future may mean that university buildings will operate throughout the year with a wider temperature variation than in the past. Given the possibility of vacation "shutdowns" next winter and the curtailment of air conditioning use in the summer, a range of from 60° to 85° seems probable. This range should be kept in mind when ordering new equipment or readjusting existing instruments. An additional investment in a more expensive piece of equipment designed for a wider ambient temperature range may be less costly than the installation of localized heating and cooling capacity.

It is hoped that the measures proposed in this memorandum will yield an energy savings of 700,000 KW hours in electricity and 4,500 barrels in fuel for the period February 1, 1974, to January 1, 1975. The university earnestly requests your cooperation.

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Appendix D-3

PURDUE UNIVERSITY

OFFICE OF THE BUSINESS MANAGER AND ASSISTANT TREASURER

WEST LAFAYETTE, INDIANA 47907

TO ALL EMPLOYEES OF PURDUE UNIVERSITY

A year ago, we asked each of you to join in a cooperative, volunteer effort to help Purdue save $180,000 in 1972-73 utility costs--funds which could be used for other programs, to pay increases, and to purchase needed supplies.

The evidence is now in and it clearly shows that you not only cooperated but went well beyond an original expectation that economies in our utility usage--water, power, lights, heat, air-conditioning, natural gas, and so on--could mean as much as a $180,000 reduction in utilities cost to be made available elsewhere in the university.

Take a bow! The combined savings in our utilities budget exceeded five percent, actually totaling $212,689! What does that mean individually? At a time when the university's operating funds are critically short, it means that many employees who received pay increases would not have gotten them because these funds otherwise would have literally gone up the stack!

An in that battle against economic and ecological waste, the amount of water saved (and thus power used to pump it out of the ground and distribute it) was a phenomenal 207,000,000 gallons, a ten percent reduction for a period in which the Physical Plant Department had expected a sharp increase.

Our power usage increased by only 20,000 kilowatt hours in 1972-73. That is a drop in the bucket, really, since the university used 129,400,000 KWH and traditionally has experienced a six to seven percent annual increase in purchase and Purdue-generated power usage.

Of course, other factors enter into the saving, but our engineers have analyzed the entire situation by several methods and now conclude that, overall, the primary reason is because people did respond to the request and did cooperate in frugal use of all of our utilities.

So, thanks to all of you, Purdue did win the battle in 1972-73--yet, the "war" goes on, and in 1973-74 we look forward to your continued cooperative effort to help save the university's resources.

Recently hundreds of time clocks were installed to assist in the most efficient use of fresh air ventilating systems, to save up to $20,000 annually. The Physical Plant staff is also conducting what eventually will be a campus-wide survey of interior lighting to reduce light to recommended levels wherever possible.

As an example of how dramatic that can be, fluorescent tubes were removed from every other fixture on the second floor of the Administrative

Services Building. Light levels are not only sufficient, but many persons have said the reduction has eased eye strain. The calculated saving in a year's time, if this reduction is extended to the rest of the building, is amazing. Reducing light levels to 100 foot-candles in this one building would mean:

-- A reduction in coal burned (to produce power) of 452.5 tons and a resultant reduction in sulphur dioxide pollutants of 11.8 tons!

-- A maintenance savings--new tubes, fixtures, etc.--of $2,210 and an operating utilities savings in one year of $10,182, or a total of $12,392.

It is not too difficult to imagine the large savings which we can make with little effort in other buildings across the campus.

A word about water: We pumped 207,000,000 gallons less last year than in the previous year. Cutting out unnecessary water usage saves not only our supply of clean water but dollars, too. We calculate that it costs five cents per 1,000 gallons to pump and distribute water through our campus mains. A small sum? Perhaps, but we must also get rid of that water and we pay nineteen cents per 1,000 gallons to let it pass through West Lafayette's sanitary disposal plant. That doesn't include, of course, some air conditioning cooling water on the central campus which we save to water our vast campus lawns.

This, in part, is what the university is doing to help save on utility costs. Here's what you can do:

1. Stay on sidewalks. Why? The university annually sods about 10 acres of new laws because of construction work and similar reasons. But one unnecessary cost is the $4,000--at about ten cents per square foot--spent to "repair" lawns where pedestrian paths have been worn.

2. Protect air conditioned and heated areas from unnecessary temperature change loads. For example, doors left open between air-conditioned and nonair-conditioned areas cost about $27 per year per door. Keep such doors closed.

3. Windows left open in air-conditioned areas cost even more--$124 per year per window. On the subject of windows, window air conditioners should be set so the thermostat can operate. For example, leaving a window air conditioner on the "constant cool" mark means the conditioner runs full blast, whether it needs to or not. Set the conditioner so the thermostat works and the compressor shuts down when not needed. Figure savings at about two cents per hour. There are at least 1,700 window units installed on campus.

4. Lights in a typical Purdue classroom cost about six cents per hour to use. Turn them off when a room is not occupied.

5. Lights in a typical residence hall room cost one half cent per hour. Consider the hourly savings if the use in each of the more than 6,000 rooms was reduced one hour per day.

6. Laboratory aspirators use two gallons of water per minute. The cost of providing water to the aspirator and of disposing of the effluent

is 60 cents per day per aspirator. There are more than 540 aspirators available in the Pharmacy Building alone, not to mention the others in other university facilities. Turn them off when not needed.

7. Laboratory hoods require 1,000 cubic feet of air per minute during operation. In air-conditioned areas, replacement air costs nine cents per hour per hood at design conditions to satisfy room conditions. Shut hoods off when not needed.

8. Access to controlled humidity areas should be kept to an absolute minimum. The "price" of opening a single door between a controlled humidity area and a corridor or uncontrolled area is two cents.

9. Consider the added cost of setting your room thermostat at 72 degrees rather than 75 in summer and 80 degrees versus 75 in winter: a typical classroom with the thermostat at 72 degrees summer and 80 degrees winter, as against a year-round 75 degree setting, costs $35 more.

10. Scheduling anticipated large electric power loads during off-peak loan periods can save hundreds of dollars annually. Example: A 25 h.p. electric motor run for one 30-minute period during the peak load periods costs $41.60 more for energy per month than if run during an off-peak period. The peak load periods here occur between 8:30 and 11:30 a.m. and from 1:30 to 4:00 p.m. on weekdays. You should reschedule anticipated large and small electrical loads to miss peak loan periods whenever possible.

If it seems that the university expends much power and water on lawn sprinkling, remember--that is one of the prices of maintaining lawns and landscaping in this climate. But remember also that the university uses air-conditioning, cooling, and condensate water whenever possible for lawn sprinkling--water that otherwise would be wasted down the drain and which could create thermal pollution in the university's drainage pond on the south edge of the Agriculture Campus. Such sprinkling is considered an ecological plus.

Most of the items mentioned here would appear to be an insignificant factor in a total utilities budget of $4.1 million when considered individually. But consider them together and we estimate that the above ten measures alone could save five percent of the total utilities expenditure in 1973-74.

A goal of five percent reduction in utilities cost by extra care on the part of all of us is not unattainable and the effort has a real dollar payoff, as we so vividly learned in the last year.

So close a door, turn off a light, shut down equipment when not in use, leave that thermostat at a constant setting. It will save <u>your</u> budget dollars. And there is another plus:

Power used at Purdue, like power used anywhere, is creating pollution for someone, somehow, someplace on this planet. When you save power, you are literally saving your environment!

L. J. Freehafer
Vice President and Treasurer

Appendix D-4

PROPOSAL FOR STUDENT PARTICIPATION IN UNIVERSITY ENERGY MANAGEMENT

The scale and diversity of the university's physical plant provide a unique source of educational opportunities for students interested in engineering, science, and the environment. The Energy Management Program is particularly receptive to student participation in its efforts to improve the efficiency of the university's energy consumption and to promote a campus-wide spirit of energy-consciousness. Paramount to the development of this "energy identity" is the need for support and active participation from all members of the university community. For students of engineering, architecture, ecology, and other applied sciences, energy conservation represents a valuable opportunity for timely and innovative research and the practical application of academic training.

In an effort to promote the mutual goals of conservation and education, the Energy Management Program has developed a list of student projects that will contribute to campus energy conservation. It should be emphasized that this list is by no means all-inclusive and that additional suggestions are encouraged.

A. PROJECTS SPECIFICALLY ASSISTING ENERGY MANAGEMENT AT THE UNIVERSITY

1. Building Energy Studies

Student teams would perform an exhaustive energy study of a single university building. This study would involve a complete energy audit and analysis of energy use with emphasis on unnecessary waste and heat loss. Students would offer recommendations for improvement of the facility--both operational and technical--and develop an engineering economy analysis of the return rate and payback period of proposed rehabilitation investments.

Implicit in this type of project is the opportunity for realistic field experience in engineer/architect and engineer/client relationships. All recommendations will be seriously considered for implementation.

Suggested projects:

a. Gymnasium (including a feasibility study for solar water heating)
b. Memorial Library
c. Laboratory

2. Topical Research in Energy Management

The following technical studies, as well as others, would provide valuable information and contribute to considerable energy savings at the university. Energy management is a new and relatively undeveloped discipline, one that will continue to solicit both basic and applied research from the academic community.

Suggested projects:

a. Building Wind-Chill Study. The influence of wind on heat loss from buildings has apparently never been thoroughly studied. Owing to the diversity of building profiles and finish materials

at the university, an analysis of the wind-chill/heat loss relationship would be invaluable to the conservation effort.

b. Solid Waste Combustion Study. The university has investigated the possibility of burning solid wastes to generate useful energy. (West Germany supplies over one-quarter of its residential electricity demand by this means.) The Conservation Program would like a detailed analysis of the financial, environmental, and logistical feasibility of establishing a solid waste combustion facility, perhaps for a specific section of the campus.

c. Fuel Oil Consumption Model. To assist in planning and budgeting, the Conservation Program would like to develop a computer simulation model of fuel oil consumption at the university. Using a large data sample, students would be asked to isolate the impacts of three major variables: wind, temperature (or air enthalpy), and building utilization.

B. PROJECTS ON ENERGY-RELATED TOPICS NOT SPECIFIC TO THE UNIVERSITY

1. Alternative Energy and/or Lifestyle Projects

The university is a uniquely qualified source for innovative research and experimentation. It is our hope that the university and other institutions of higher education will apply themselves to the study of energy resource management with the same determination and spirit of public service that is now evidenced in science, medicine, and engineering.

One particularly valuable class exercise that has been developed at other schools is the design and construction of small-scale alternative energy systems. These can include solar heating, cooking, water distillation, and wind electric generation and devices and have, on occasion, led to patented and marketable products. These have, in turn, brought considerable publicity to the cause of energy conservation and to the students and departments involved.

2. General Energy-Related Research

There is an almost unlimited need for original and socially valuable research in the following areas:

a. Energy production.

b. Energy consumption and the improvement of consumption efficiency.

c. Resource conservation, including recycling, aquaculture, methane generation, and the treatment of water and sewage.

d. The impact of our environment and "quality of life" caused by alternative energy production, consumption, and storage systems.

It is hoped that the academic sector will assume a vital leadership role in forging and maintaining an energy-conscious society. The Conservation Program at the university is eager to enlist cooperation in its efforts to reduce costs and save nonrenewable fuel resources.

Appendix E: Elements of a Contract with an Energy Consultant

1. Services to be provided: Based on an analysis of rates, the consultant typically will furnish recommendations for savings and refunds on purchased utilities. The initial examination usually would cover bills for the last 12 months. Continuing analysis would cover current bills, to be sent by the institution to the consultant each month during the period of the agreement. Where applicable, old bills should be reviewed as far back as possible for refunds.

2. Negotiations with suppliers of utility services: These would be conducted by the institution unless otherwise agreed upon by both parties.

3. Period covered by agreement, along with provision for cancellation by either party.

4. Payment terms:

a. Service fee, such as a percentage of annual utility expenses, with a minimum and maximum.

b. Percentage of each refund secured, and percentage of each cash savings secured for a specified time.

c. Exceptions to agreement for sharing in refunds or savings, such as the lowering of rate schedules where the lowering is not influenced by the consultant's recommendations, change in suppliers or in types of fuel, and installation of a facilities management system.

Glossary

ANSI—American National Standards Institute.

ASHRAE—American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Btu—British thermal unit; the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2°F.

CBM—Certified Ballast Manufacturers (Association).

cfm—cubic feet per minute.

dew point—the temperature at which air becomes saturated and produces dew.

foot-candle—the illumination of a surface one foot distant from a source of one standard candle (or candela), equal to one lumen per square foot.

gpm—gallons per minute.

HID—high-intensity discharge (lamps).

HVAC—heating, ventilating, and air conditioning.

kilowatt-hour—a unit of work or energy equal to that expended by one kilowatt (1,000 watts) in one hour; a watt is the unit of power equal to the rate of work represented by one ampere under a pressure of one volt (1/746 hp).

lumen—a unit of luminous flux equal to the light emitted in a unit solid angle by a uniform point source of one candle.

MB/DOE—million barrels per day of oil equivalent (see appendix A-2 for conversions).

mcf—thousand cubic feet.

psig—per square inch gauge (as contrasted with psia, per square inch absolute).

r.h.—relative humidity; the ratio of the amount of water vapor in the air at a specific temperature to the maximum capacity of the air at that temperature.

short ton—2,000 pounds, or .907 metric tons (a metric ton equals 1,000 kilograms); a long ton equals 2,240 pounds, or 1.12 short tons, or 1.016 metric tons.

VAV—variable air volume (type of heating-cooling system).